Future Circular Collider

Technical Infrastructure

Ventilation strategy for FCC

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FCC Week 2024

Outline

1. Aims and scope of Ventilation

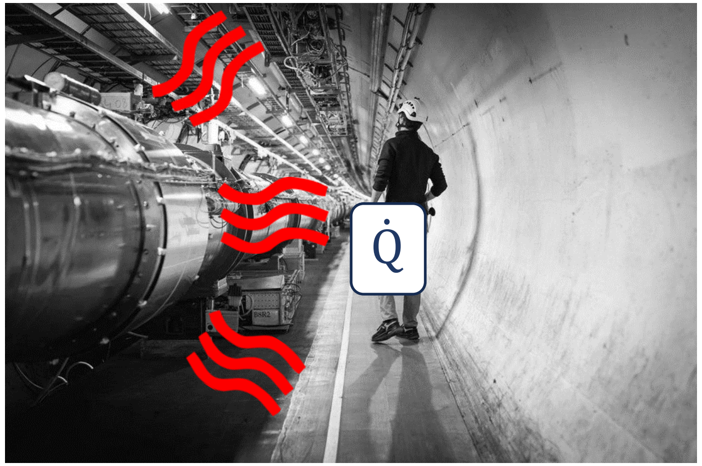
1. Aims and scope of Ventilation *Introduction*

1. Ventilation in conditioning

- Regulation and conditioning of air (mainly temperature, humidity) when machines are running and when workers access facilities

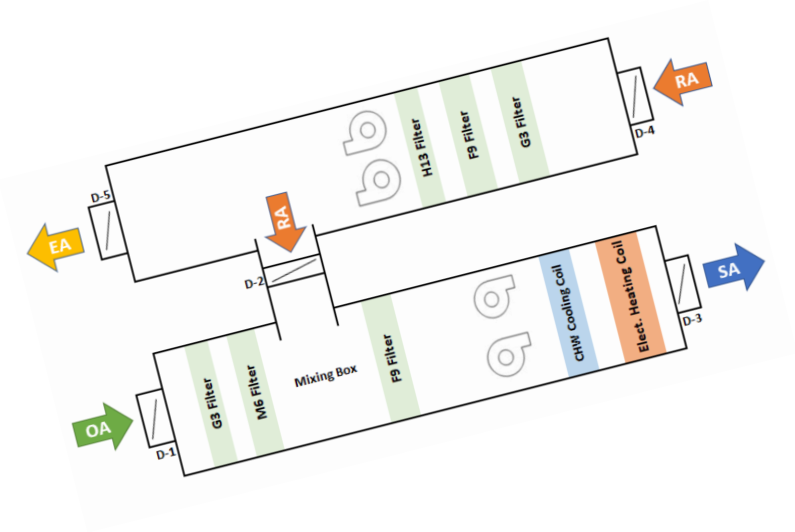
2. Ventilation in heat load dissipation

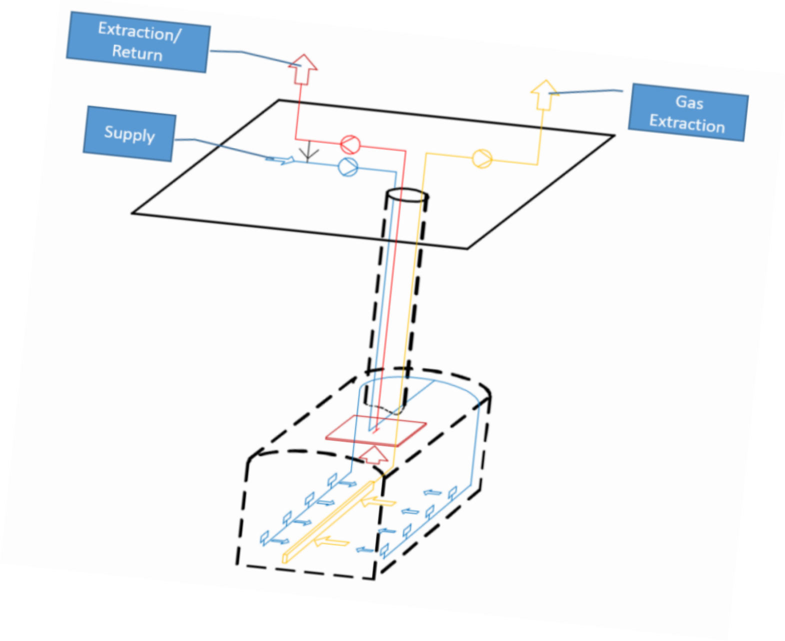
- Transfer of part of the thermal load produced in the machines and racks to the air renewed by ventilation



3. Ventilation in emergency cases

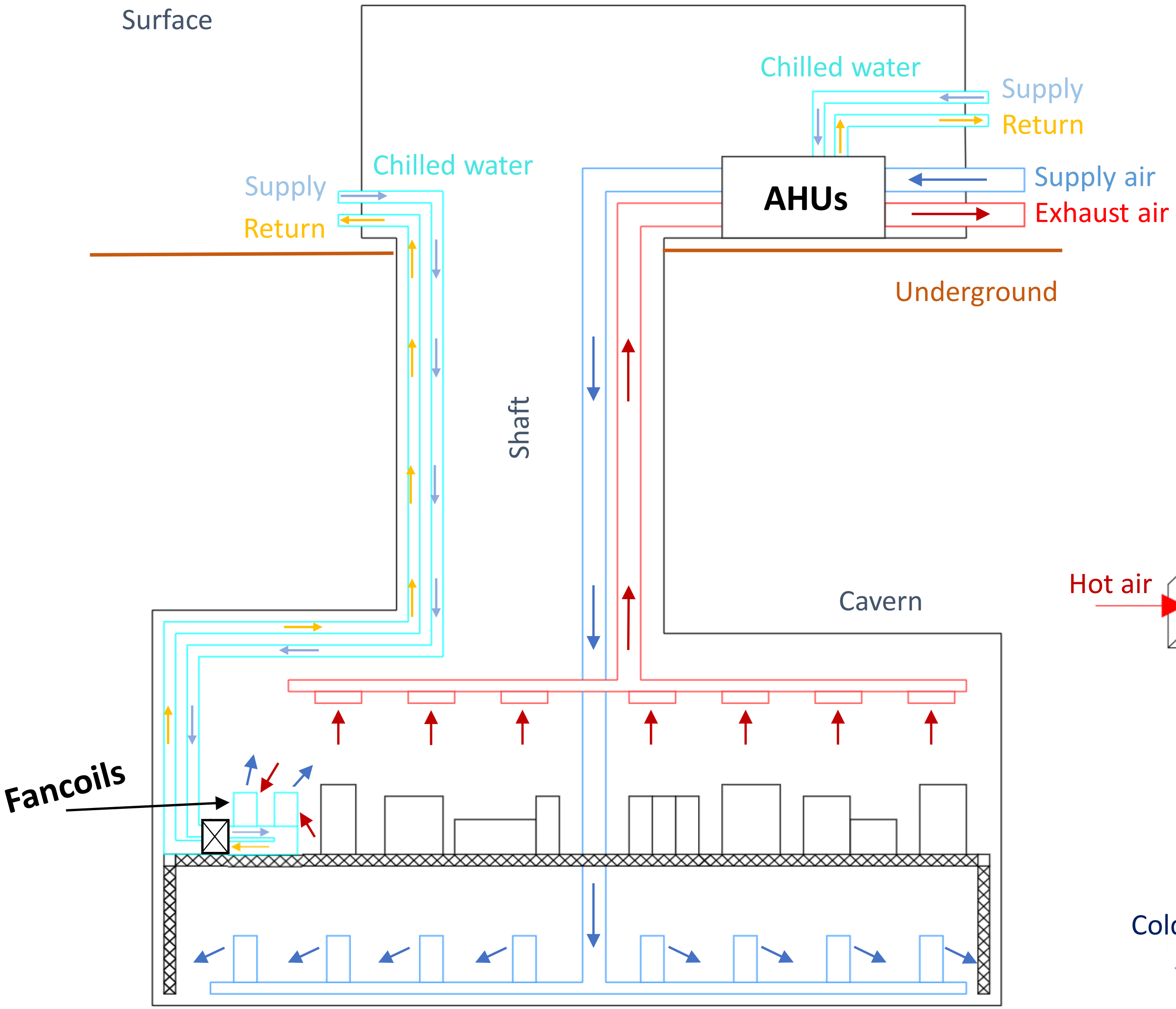
- Extraction of smoke or helium in case of emergency and creation of safe conditions in compartments





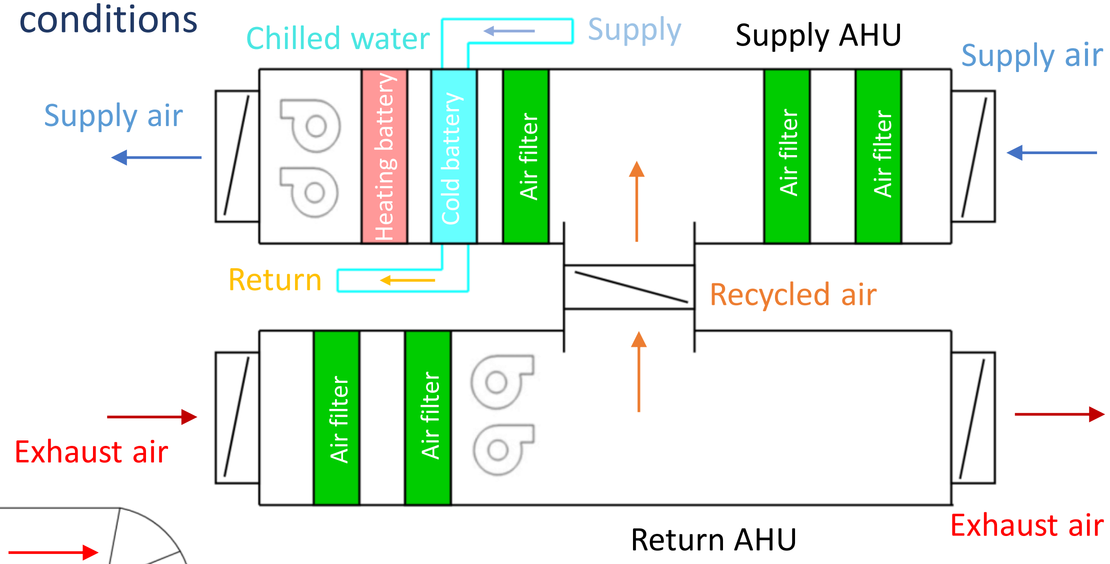
2. Technical details on Ventilation Design for FCC

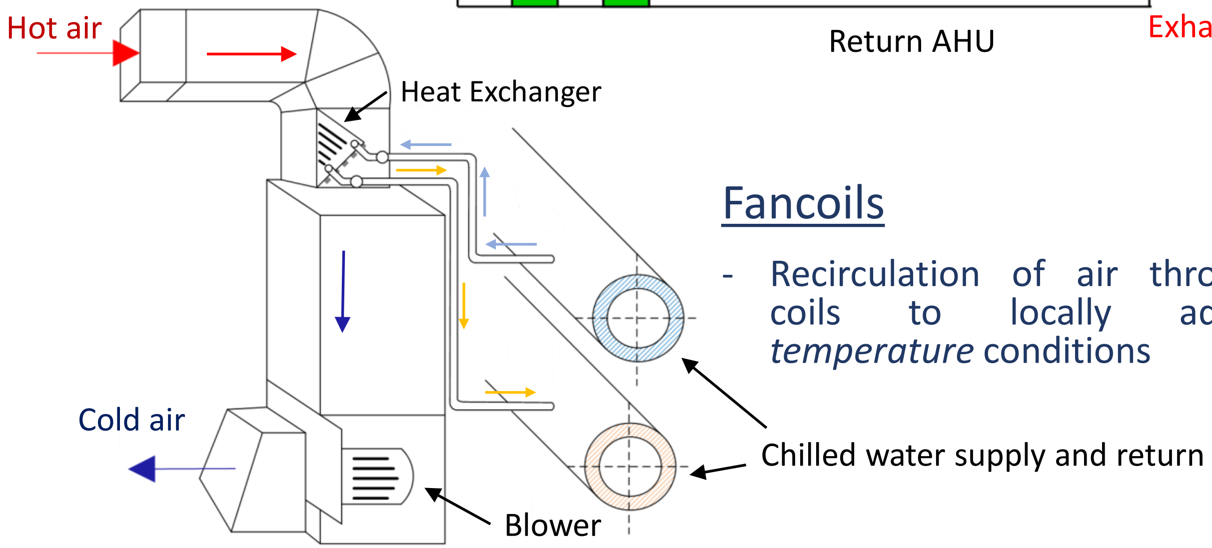
2.1 Generalities *AHUs & fancoils*



AHUs

- Treatment of the air to *temperature* and *humidity* conditions





Fancoils

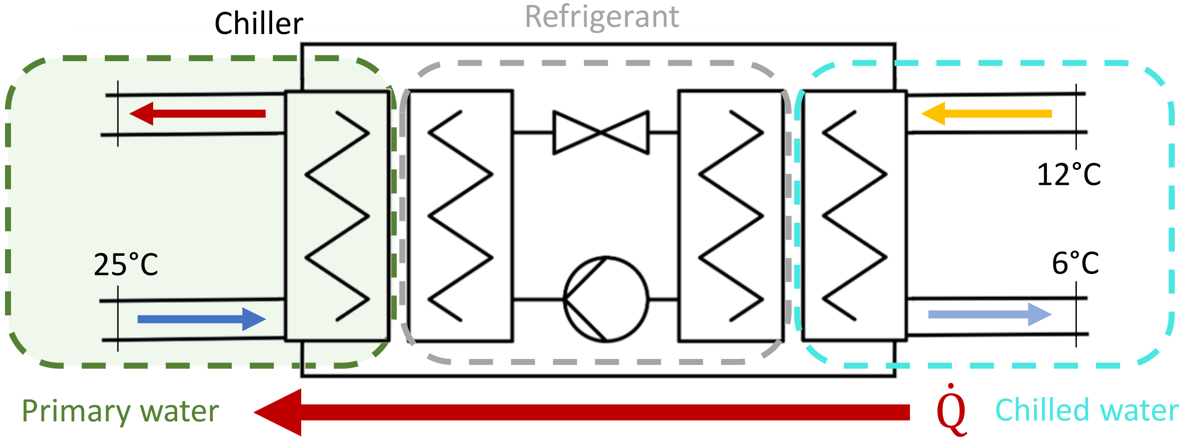
- Recirculation of air through coils to locally adjust *temperature* conditions

2.1 Generalities

Primary circuit heat loads

FCC-ee COOLING POWER NEEDS FOR PRIMARY CIRCUITS (MW)

Point	Cryogenics	Experiment	General Services	Power Converters (RF)	Chilled water	Underground	TOTAL
A	0.3	0.5	2		4.6	42.6	**50**
B			2		3.9	1.0	**7**
D	0.3	0.5	2		4.6	42.6	**50**
F			2		3.9	1.0	**7**
G	0.3	0.5	2		4.6	42.6	**50**
H	34		2	4.5	10.1	51.0	**102**
J	0.3	0.5	2		4.6	42.6	**50**
L	10		2	0.1	4.5	2.7	**19**



Ventilation cooling requirements
in Primary Water Circuit

More info:
G. Peon @ Session TIWG 5

2.1 Generalities

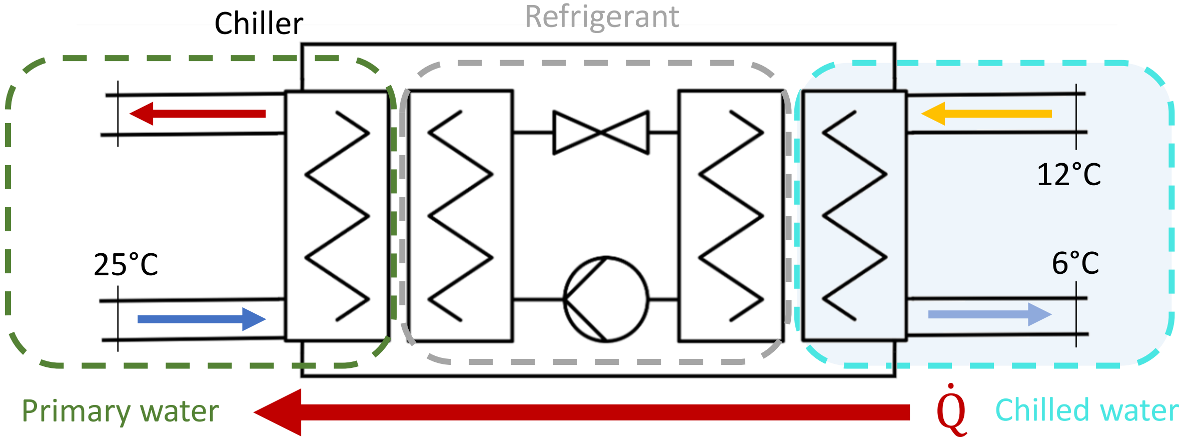
Chillers needed

POINT	COOLING POWER (kW)	FLOW RATE (m^3/h)	NUMBER OF CHILLERS	COOLING POWER/ CHILLER (kW)
A	3,848	553	5	1,000
B	3,284	472	5	900
D	3,828	550	5	1,000
F	3,284	472	5	900
G	3,848	553	5	1,000
H	8,345	1,200	6	1,800
J	3,828	550	5	1,000
L	3,739	537	5	1,000

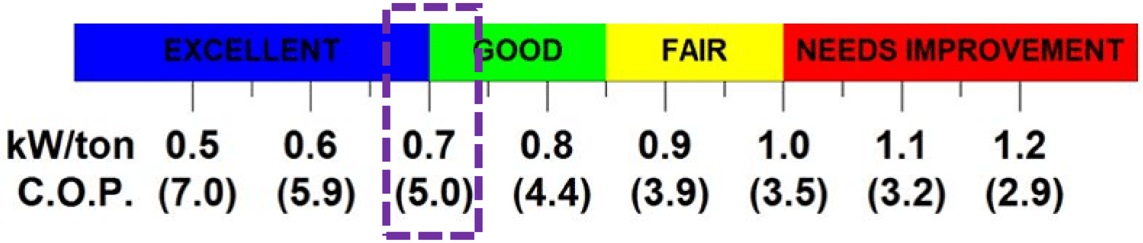
Ventilation cooling requirements in Chilled Water Circuit.

Cold batteries in AHUs / Fancoils in:

- Surface Buildings
- Shaft pressurization
- Service Cavern & UAs
- Experimental Cavern
- Half Tunnel Sector 1
- Half Tunnel Sector 2
- Klystron Galleries



COP ≈ 5



2.1 Generalities

Chilled water circuit heat loads

1. Surface heat loads to chilled water (kW)							
POINT	Cryogenics	Power Converters	General Services	Experimental Areas	Shaft Pressurisation	Fresh Air for Underground Areas	TOTAL TO CHILLED WATER
A	13		500	50	300	150	**1013**
B			500		150	50	**700**
D	13		500	40	300	150	**1003**
F			500		150	50	**700**
G	13		500	50	300	150	**1013**
H	1,400*	2,250*	500		150	150	**800**
J	13		500	40	300	150	**1003**
L	402*	35*	500		150	150	**800**

*Extracted without chilled water → Option: free cooling

Chilled water load = 1. Surface + 2. Underground + 3. Sector

3. Sector heat loads to chilled water (kW)				
Magnets	Cables	Synchrotron radiation absorbers	Alcoves	TOTAL PER SECTOR
352	1,642	250	120	**2,364**

Depends on number of alcoves:
- 3,500 for 7 alcoves (baseline)
- 1,500 for 9 alcoves (optimal)

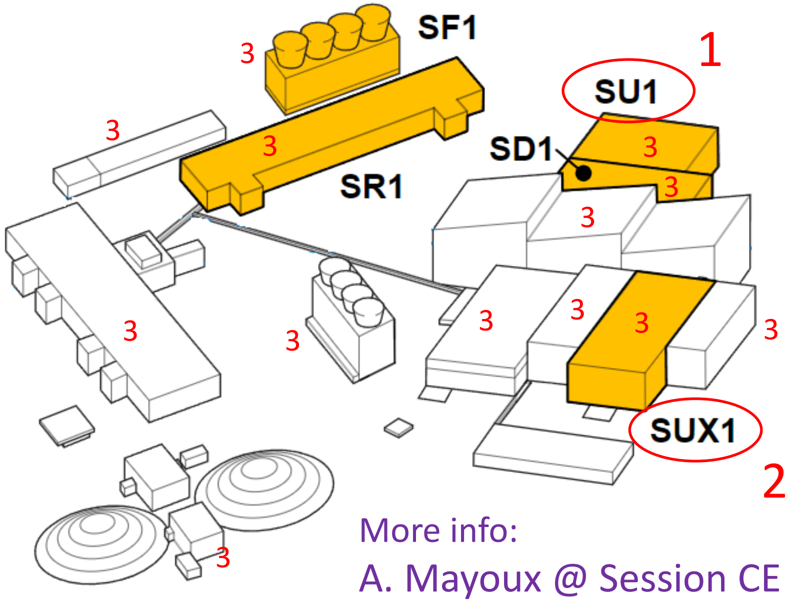
More info:
B. Wicki @ Session TIWG 3

2. Underground heat loads to chilled water (kW)						
POINT	Cryogenics	RF	Experimental Areas	Power Converters	Ventilation UW	TOTAL
A	1		50	220	200	**471**
B				220		**220**
D	1		40	220	200	**461**
F				220		**220**
G	1		50	220	200	**471**
H	145	4,600		220	200	**5,165**
J	1		40	220	200	**461**
L	60	75		220	200	**555**

2.2 Surface Areas

Requirements for Ventilation

Buildings with CV equipment, LHC Point 1



1. SU building *CV building*

- *SU-CW:*
  - Chilled water production station
- *SU-VT:*
  - AHUs of the Tunnel
  - In Points B, F, H, L; AHUs of the Service Caverns and UAs → small

2. SUX building *CV building*

- *SUX-MC:*
  - In Points A, D, G, J; AHUs of the Experimental Cavern.
  - In Points H, L; AHUs of Klystron Galleries.
- *SUX-TC:*
  - In Points A, D, G, J; AHUs of the Service Caverns and UAs

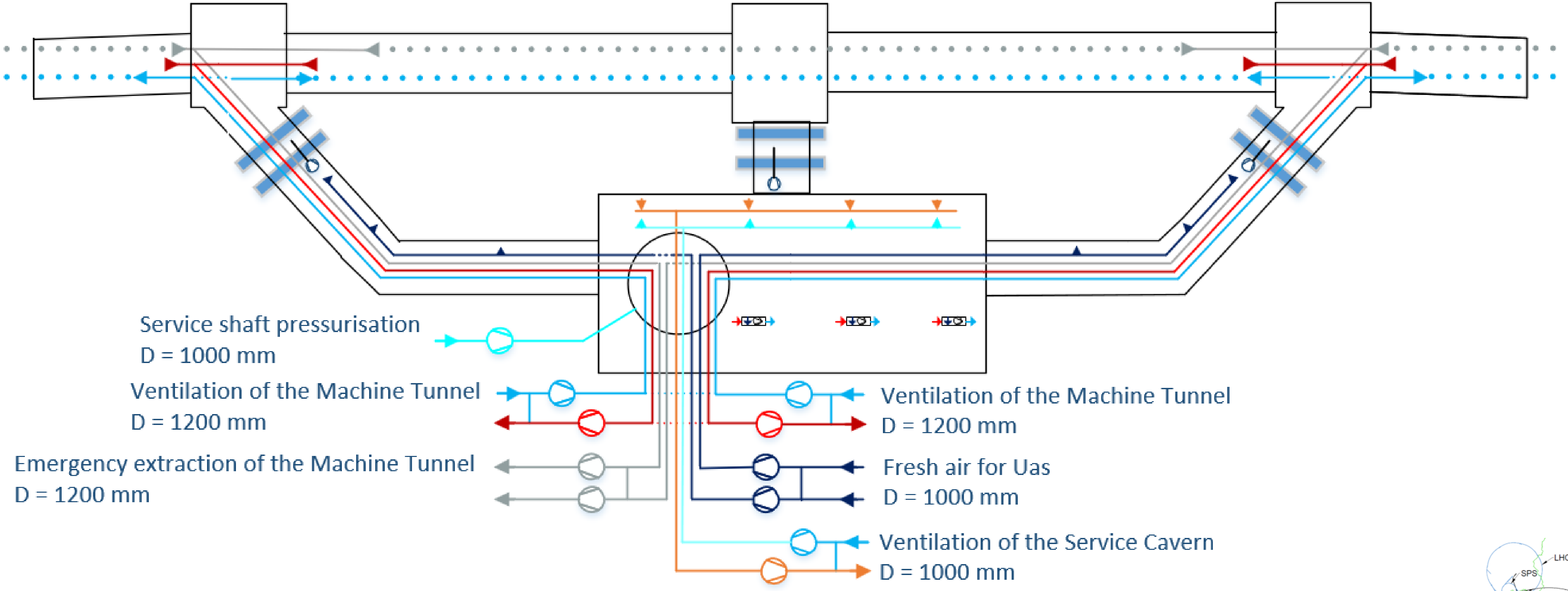
3. All surface buildings *Ventilation of all buildings*

- Conventional on-shelf equipment
- Special equipment, e.g. clean rooms

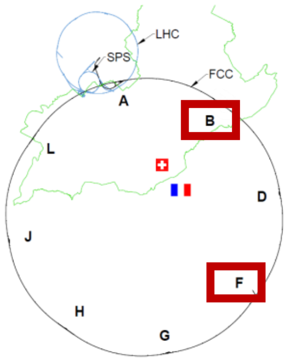
Building official nomenclature to be defined!

More info:
A. Mayoux @ Session CE

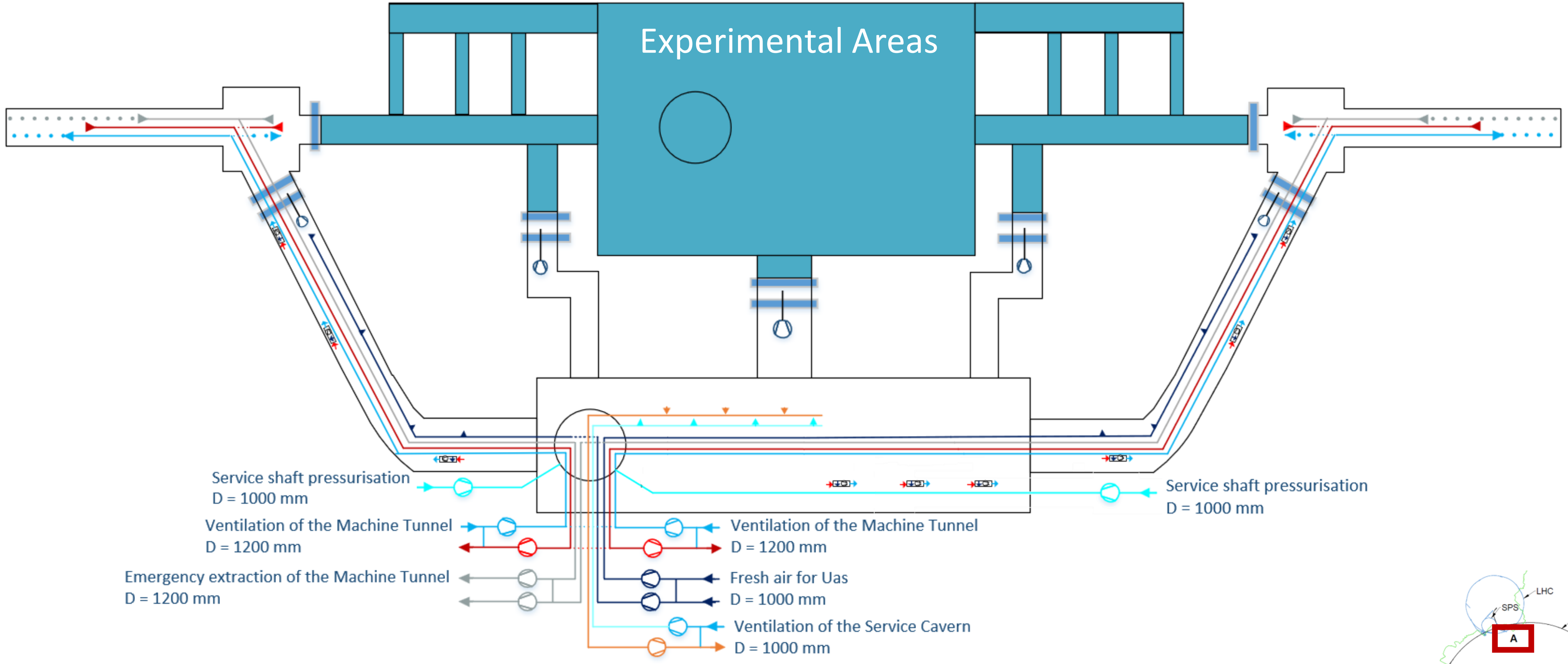
2.3 Technical Areas *in Technical Points (B,F)*



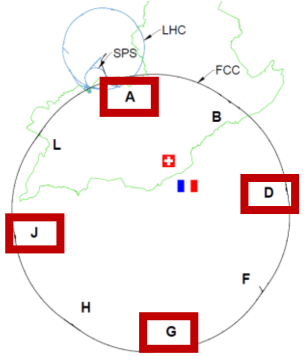
	Air Supply	Extraction	Emergency extraction
Technical Points B, F	Fresh air UAs: 20,000 m^3/h Ventilation Service Cavern: 20,000 m^3/h	40,000 m^3/h	40,000 m^3/h



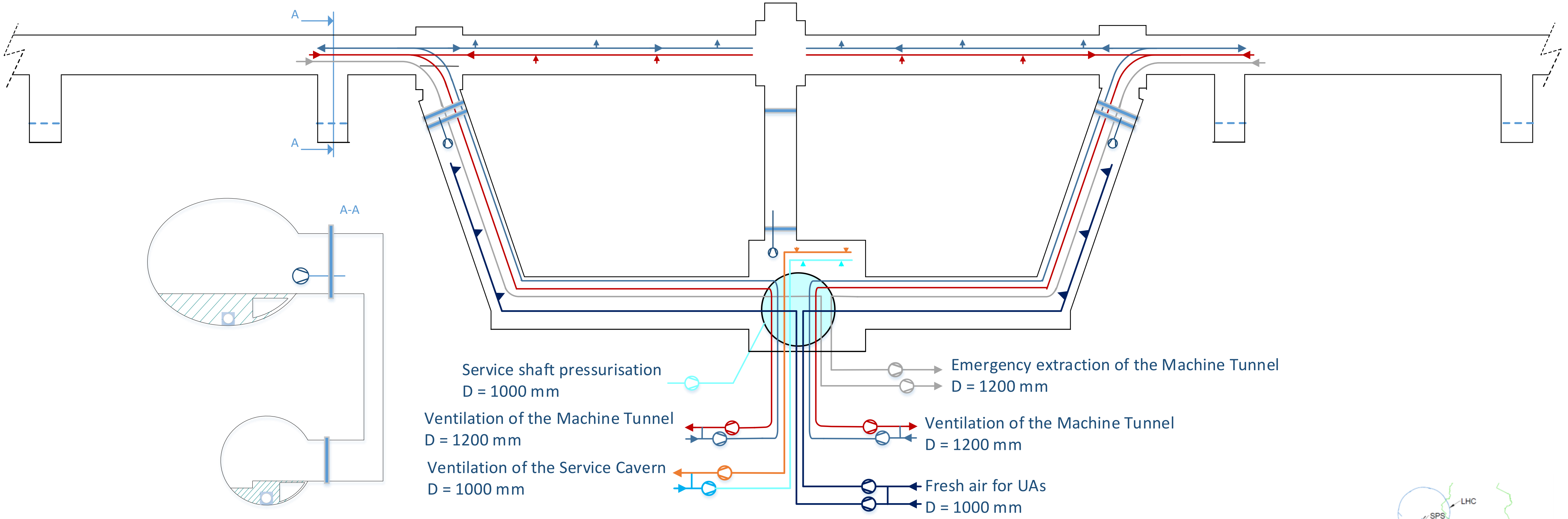
2.3 Technical Areas *in Experimental Points (A,D,G,J)*



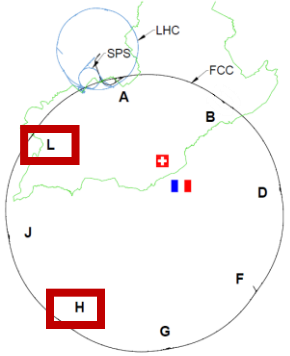
	Air Supply	Extraction	Emergency extraction
Experimental Points A, D, G, J	Fresh air UAs: 20,000 m^3/h Ventilation Service Cavern: 40,000 m^3/h	60,000 m^3/h	60,000 m^3/h



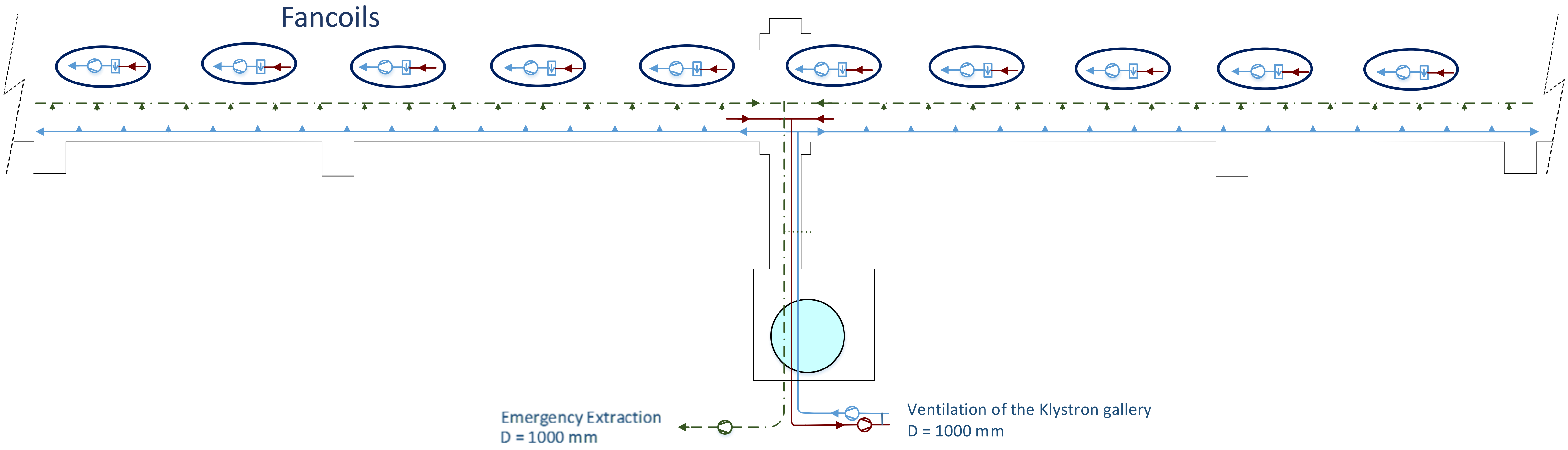
2.3 Technical Areas *in RF Points (L,H)*



	Air Supply	Extraction	Emergency extraction
RF Point	Fresh air UAs: 20,000 m^3/h Ventilation Service Cavern: 20,000 m^3/h	40,000 m^3/h	40,000 m^3/h

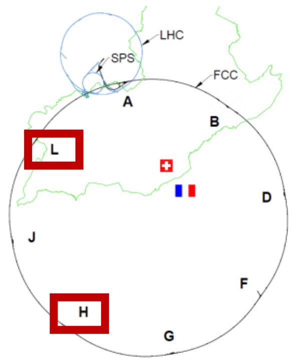


2.4 RF Areas *in RF Points (L,H)*

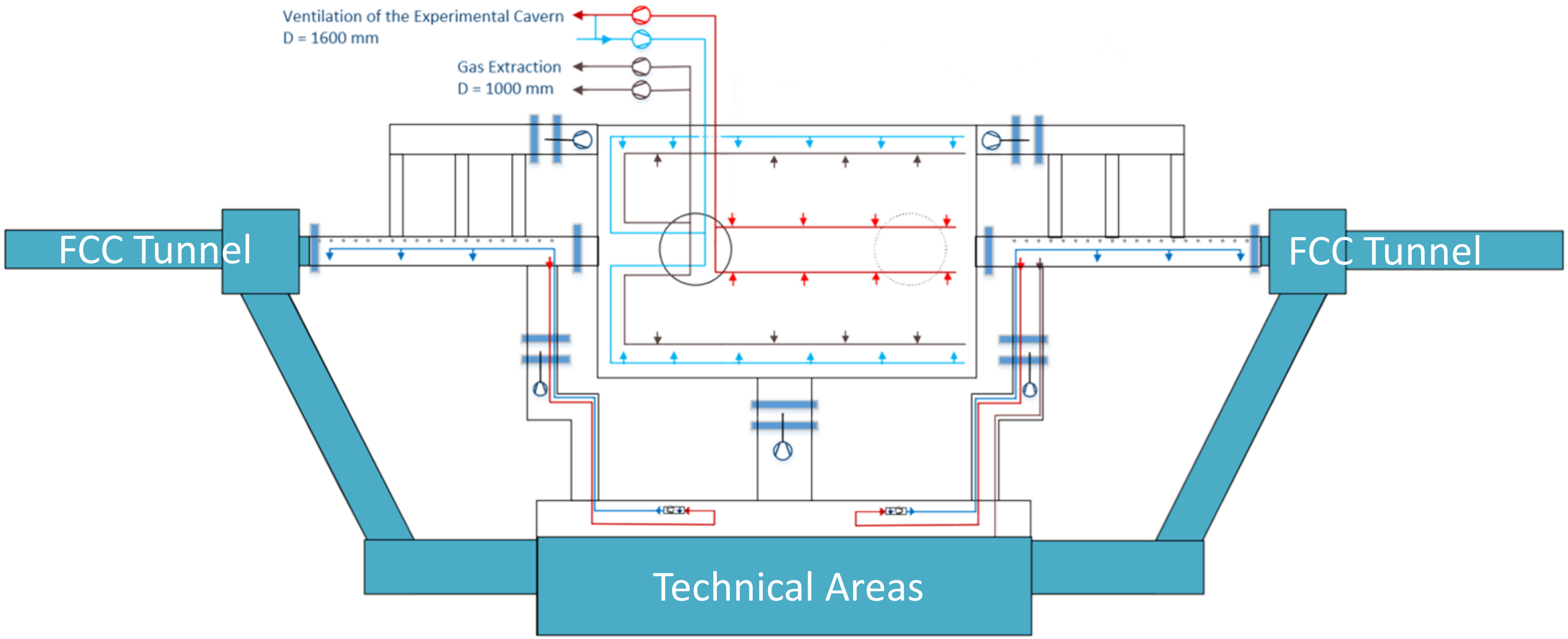


Equivalent compartment structure as in the Tunnel

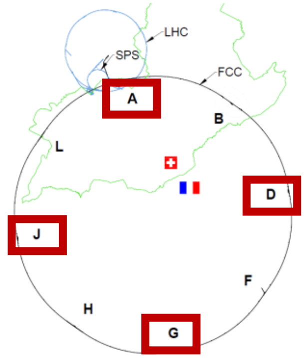
	Air Supply	Regular Extraction	Emergency Extraction
Run & Access Mode	30.000 m^3/h	30.000 m^3/h	OFF
Emergency conditions	> 30.000 m^3/h	< 30.000 m^3/h	7000 m^3/h in affected compartments (max. 2) 6000 m^3/h in adjacent compartments (max. 2)



2.5 Experimental Areas *in Experimental Points (A,D,G,J)*



	Air Supply	Regular Extraction	Gas Extraction
Run & Access Mode	50.000 – 70.000 m³/h	50.000 – 70.000 m³/h	OFF
Flushing Mode	50.000 – 70.000 m³/h	50.000 – 70.000 m³/h	OFF
Fire Emergency	Up to 70.000 m³/h	Up to 70.000 m³/h	OFF
Gas Emergency	20.000 m³/h	OFF	20.000 m³/h



2.6 Tunnel *General parameters*

General Input data	
Cross section area	15.2 m^2
Sector length	11,396 m
Max. Temperature (running conditions)	32°C (to be confirmed)
Max. dew point Temperature	12°C (to be confirmed

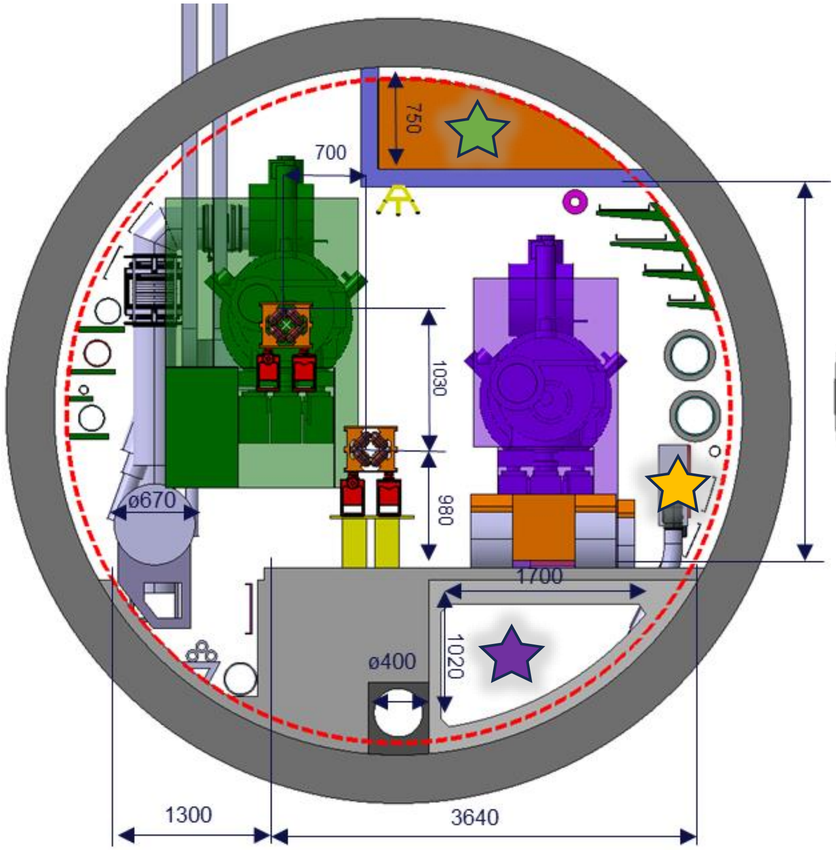
Compartment Input data	
Number of Compartments	29
Compartment length	400 m
Volume Compartment	6,080 m^3

Ventilation parameters	
Normal operation air flow per sector	2 x 27,000 m^3/h
Flushing air flow (longitudinal) per sector	100,000 m^3/h
Air supply points per compartment	4
Air flow per supply point (normal operation)	474 m^3/h
Time to complete air renewal (flushing)	1.7 h
Maximum air speed (normal operation – flushing)	0.5 m/s – 1.8 m/s
Cooling capacity in normal operation for ΔT = 15 K per sector	271 kW

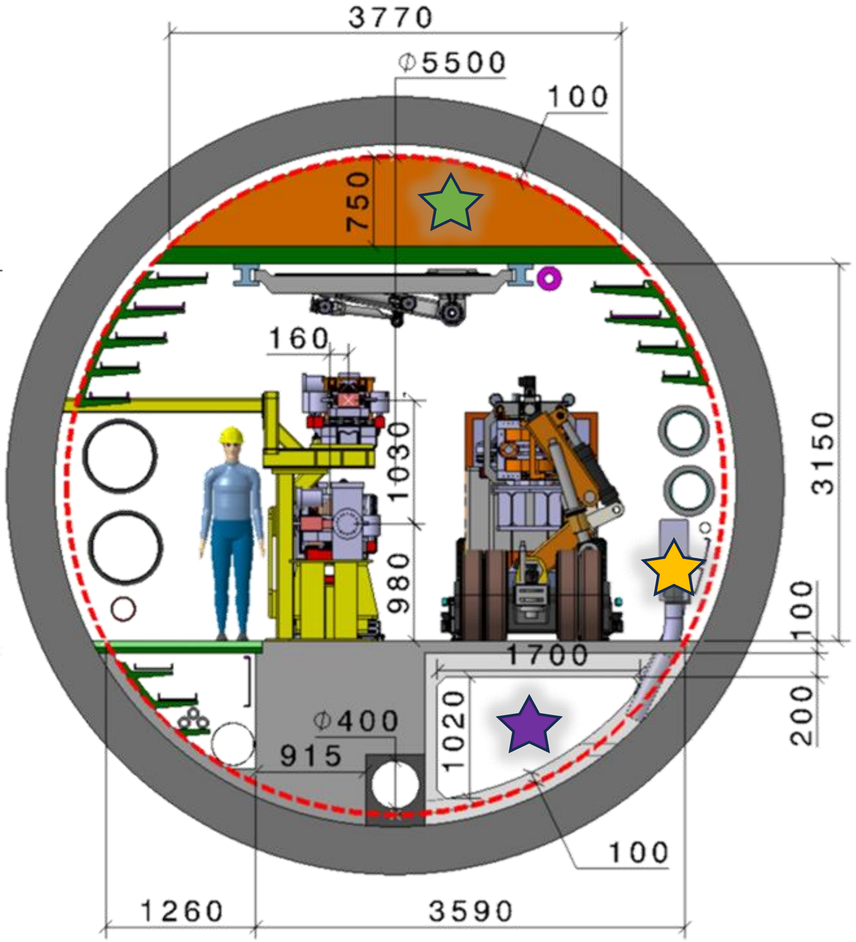
2.6 Tunnel *Integration*

- Smoke extraction duct + dampers
- Inlet slab duct
- Fancoils & air terminal units *(alternated longitudinally)*

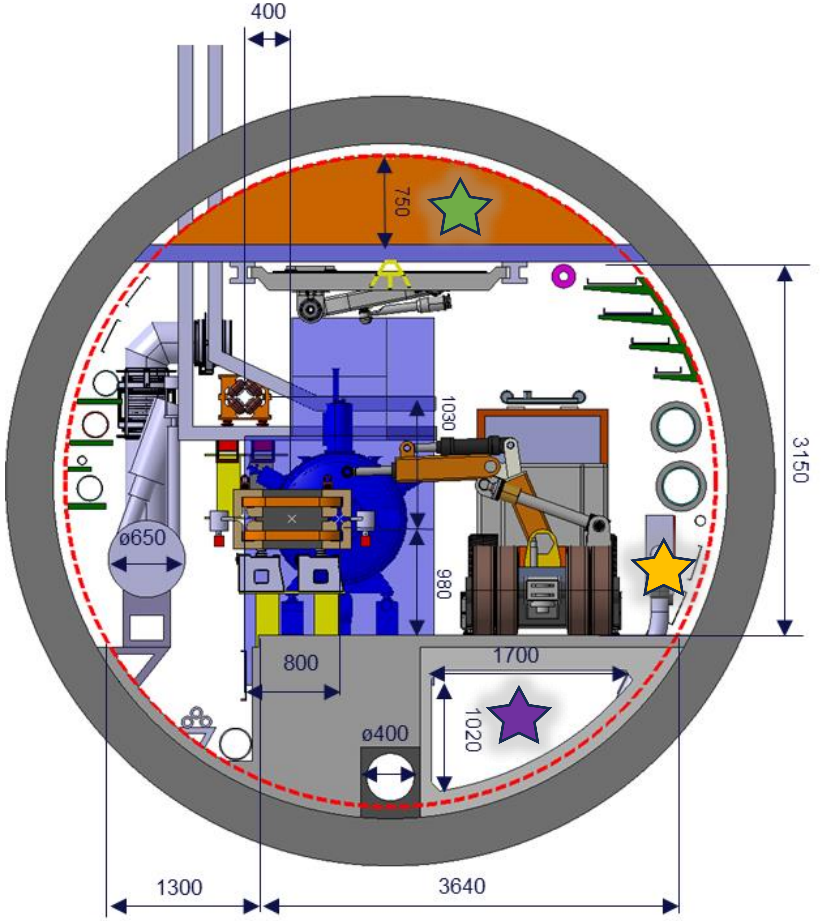
More info:
F. Valchkova @ Session TIWG 3



Point L RF Arc

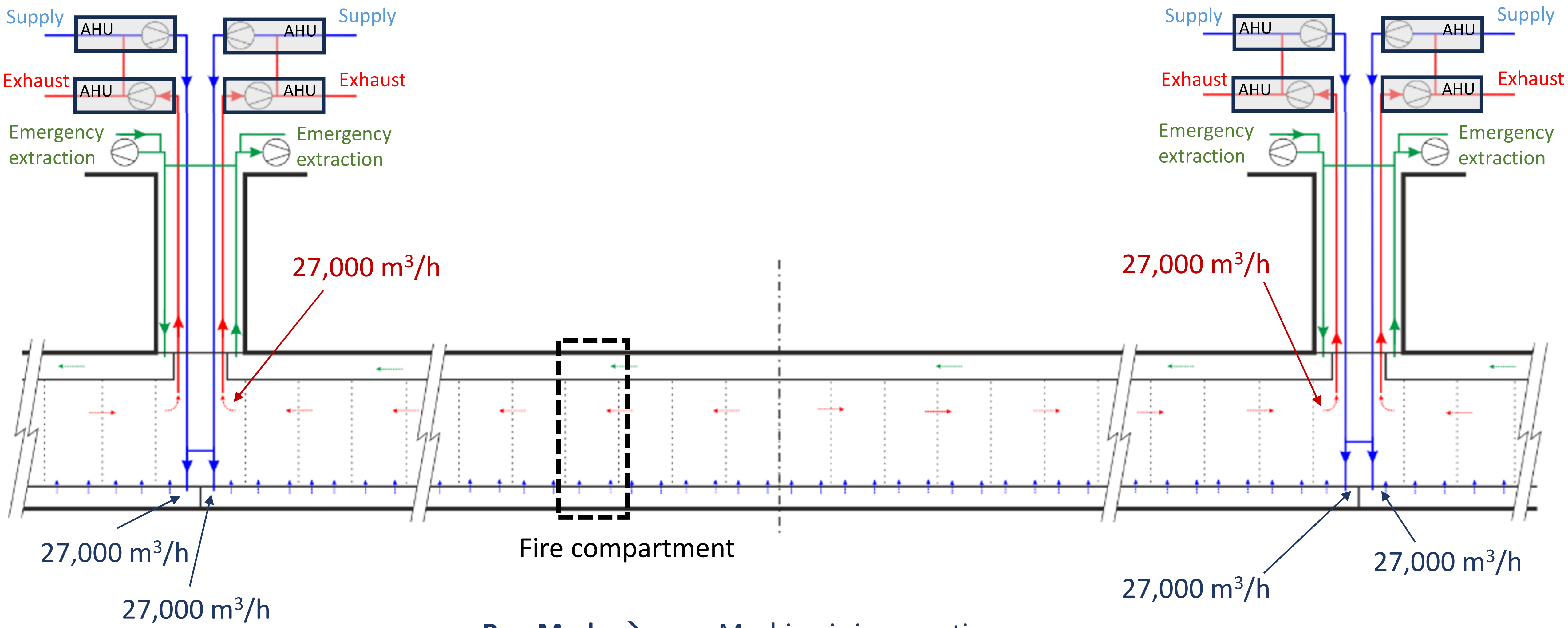


Tunnel in Arc



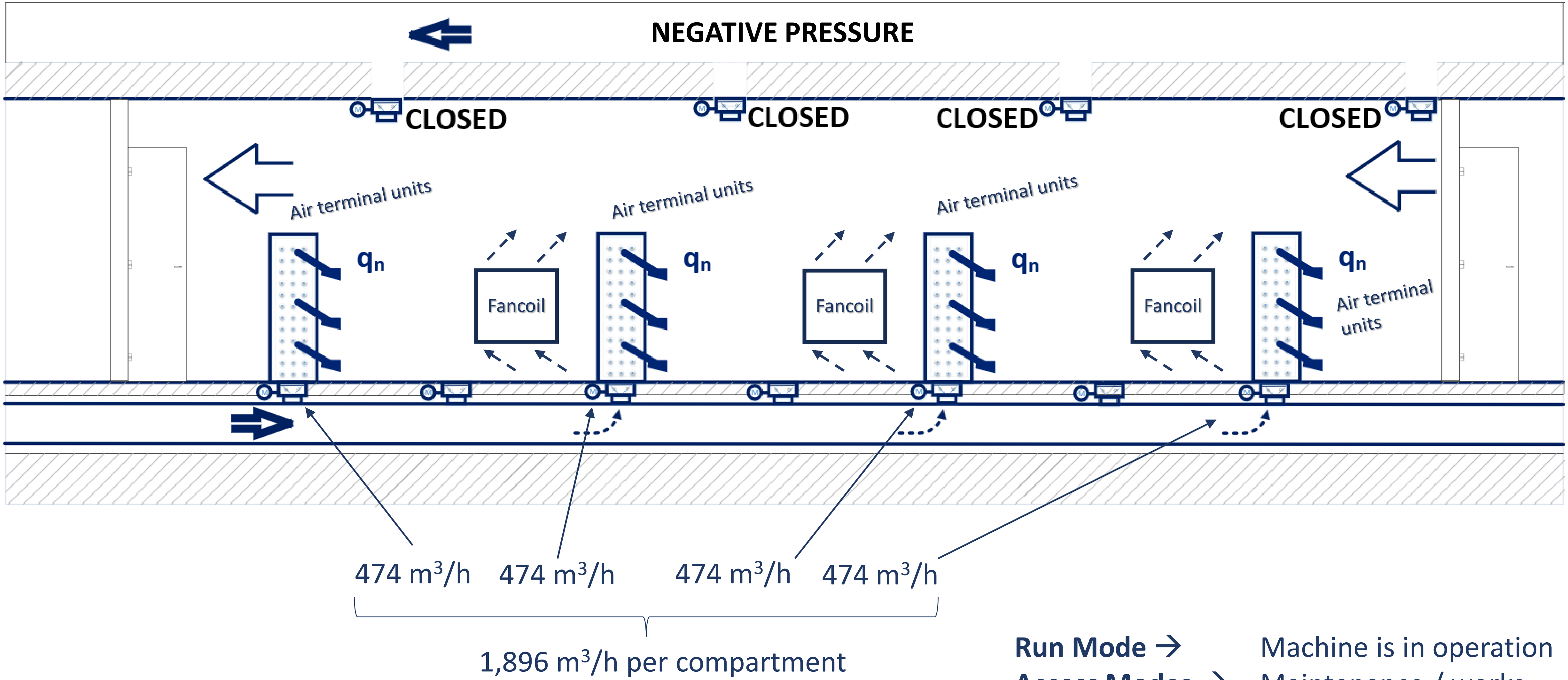
Point H RF Arc

2.6 Tunnel *Run & Access Modes*



Run Mode → Machine is in operation
Access Modes → Maintenance / works are done in the tunnel

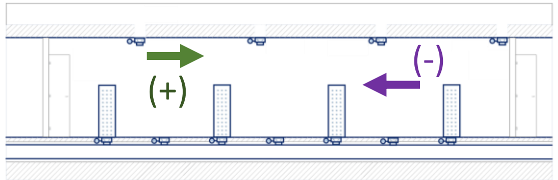
2.6 Tunnel *Run & Access Modes*



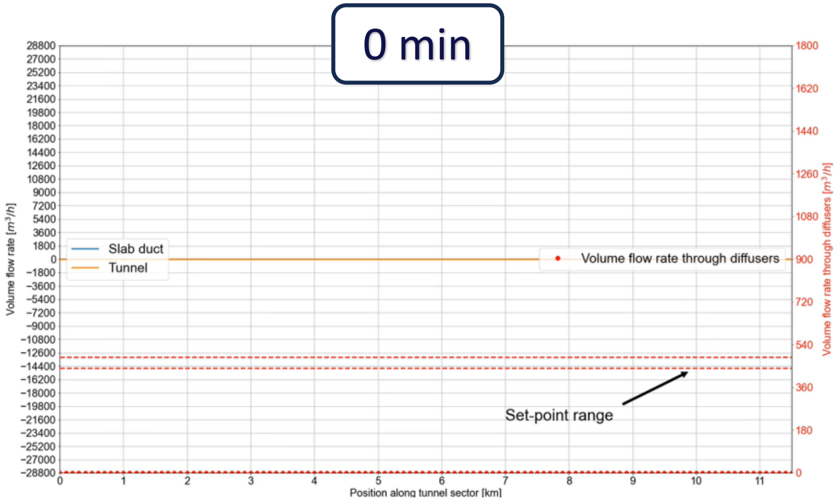
Run Mode → Machine is in operation

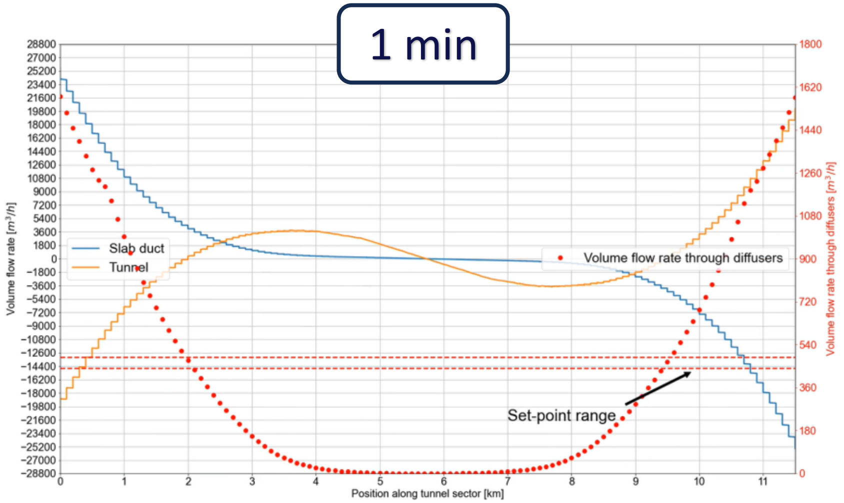
Access Modes → Maintenance / works are done in the tunnel

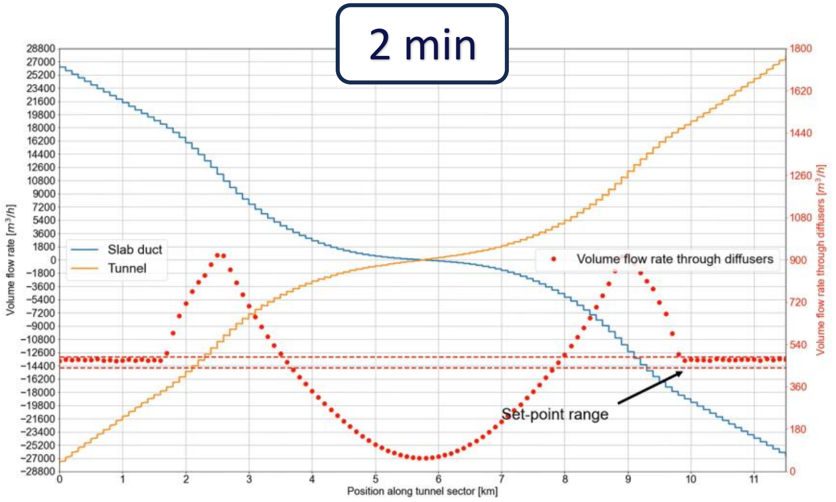
2.6 Tunnel *Run & Access Modes Transient, OFF → Run/Access*

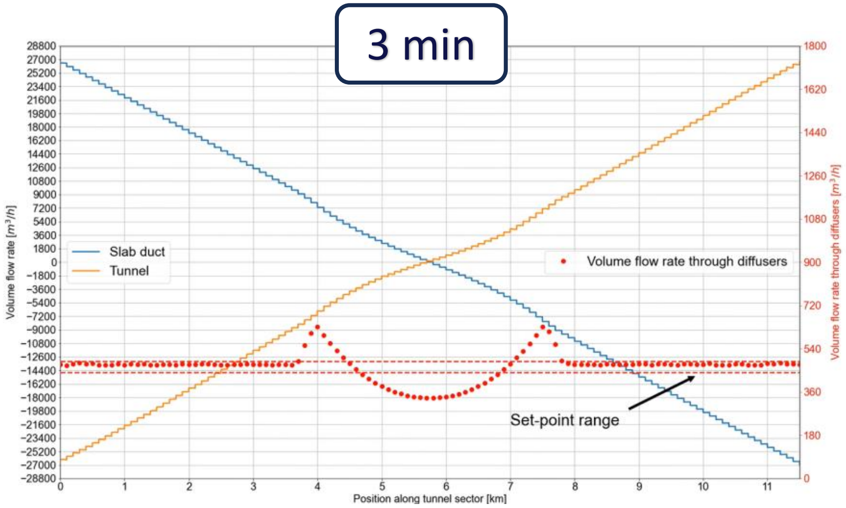


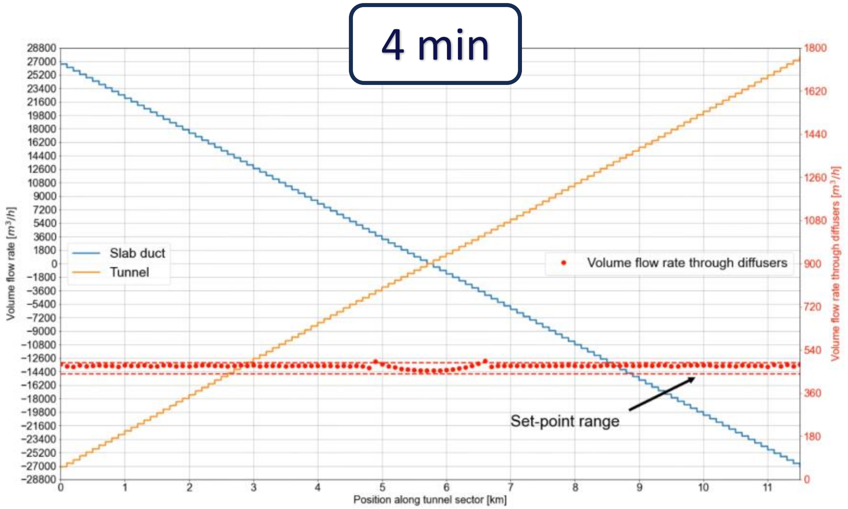
Signs criteria

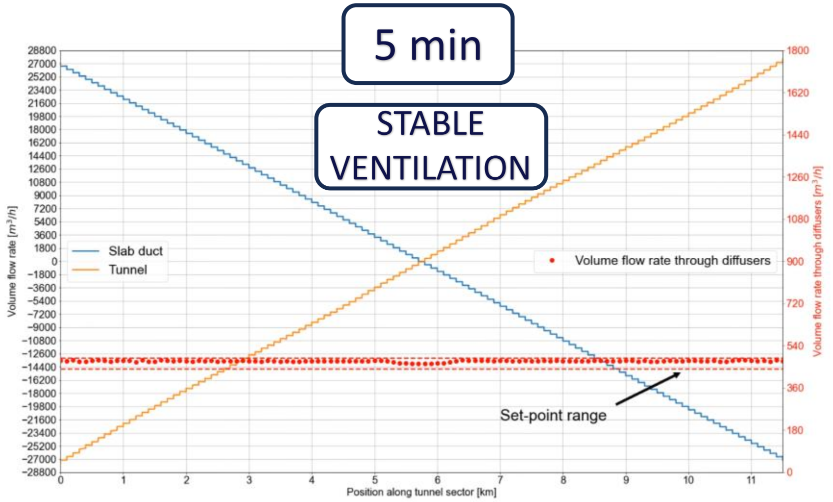




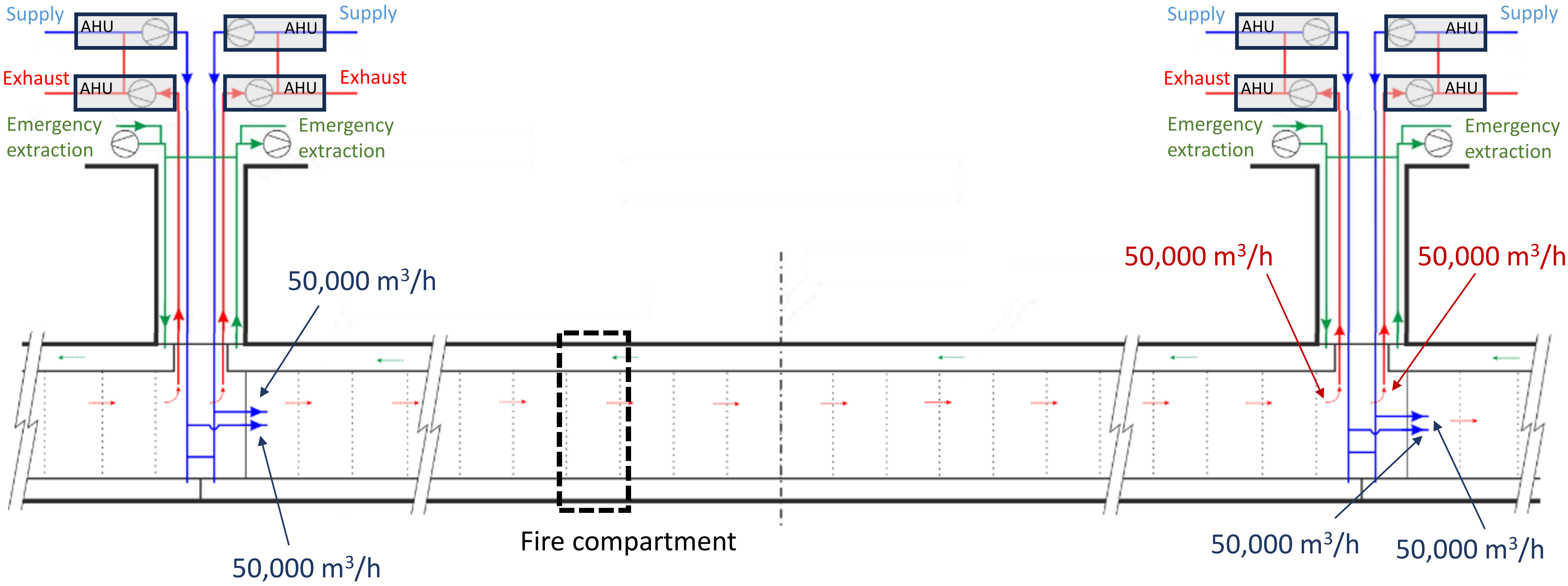






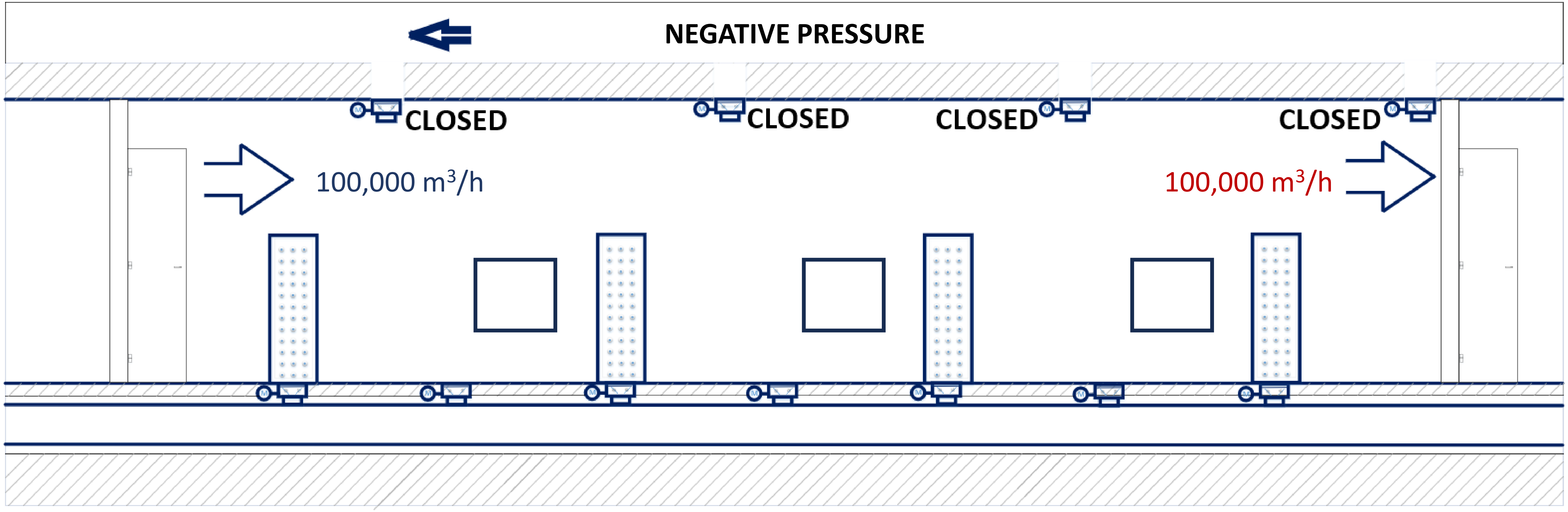


2.6 Tunnel *Flushing Mode*



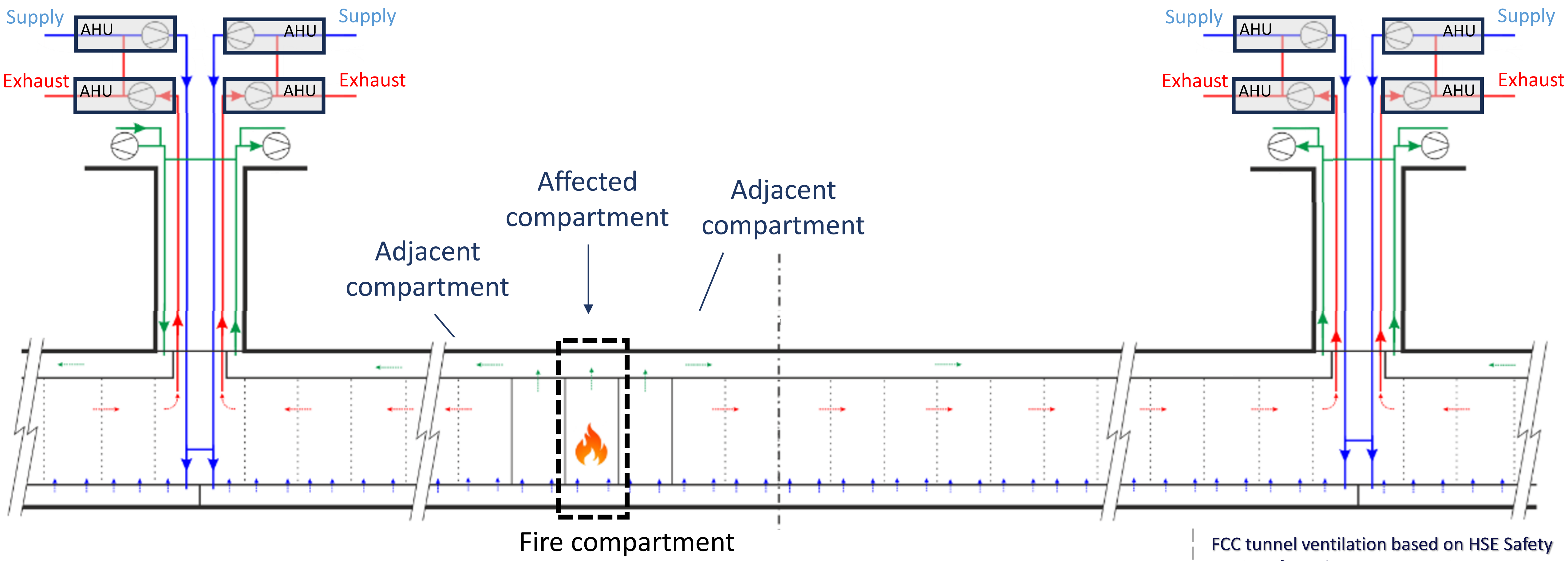
Flushing Mode → Full air renewal between Access and Run Modes

2.6 Tunnel *Flushing Mode*



Flushing Mode → Full air renewal between Access and Run Modes

2.6 Tunnel *Emergency Mode*



Emergency Mode → Smoke & fire or helium leak scenario

More info:
A. Henriques, O. Rios @ Session TIWG 1

Tunnel Fire Dynamics. Springer, 2015
Ingason H., Li Y.Z., Lönnermark A.

10 m³/s ← 5 kg/s; 4 MW; 3.25 m – 0.5 m

$$m(z) = 0.071 \cdot Q_c^{1/3} \cdot z^{5/3}$$

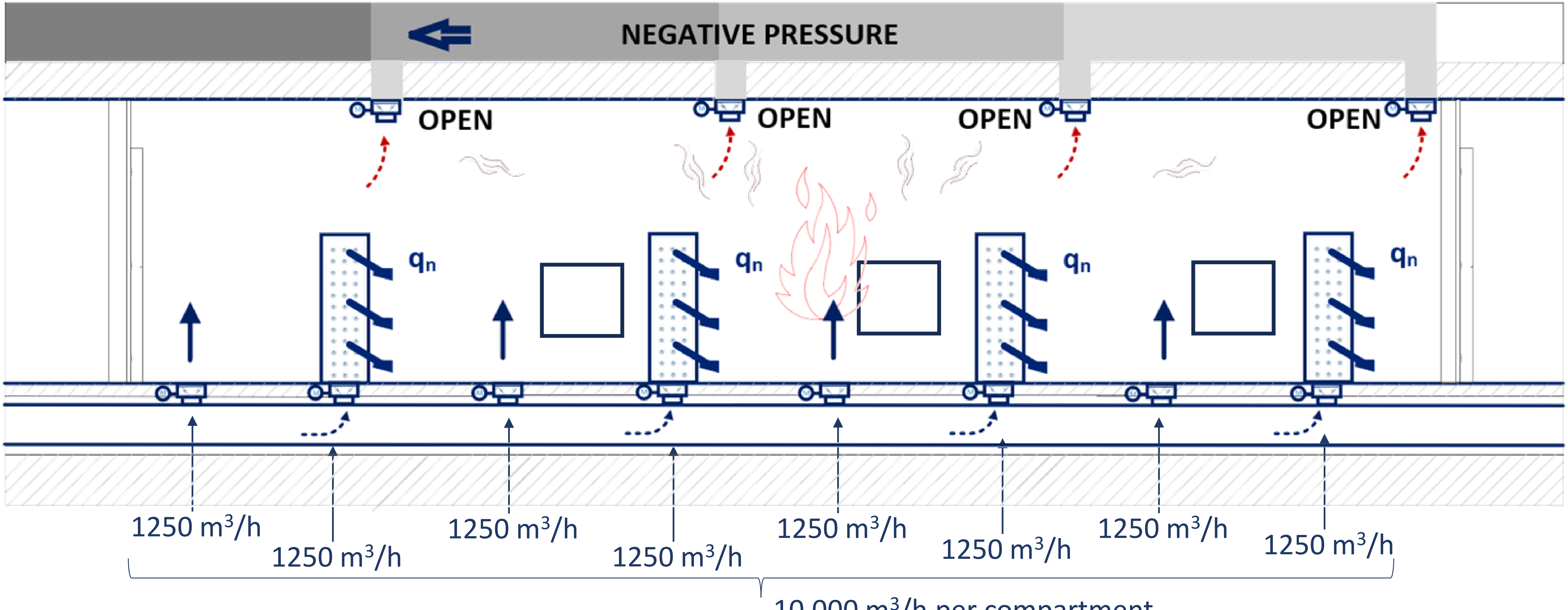
FCC tunnel ventilation based on HSE Safety studies → Performance Based Design

Need	Capacity
4 m^3/s	4.7 m^3/s (10000 + 2*3500) m3/h

EDMS 1817646

2.6 Tunnel *Emergency Mode*

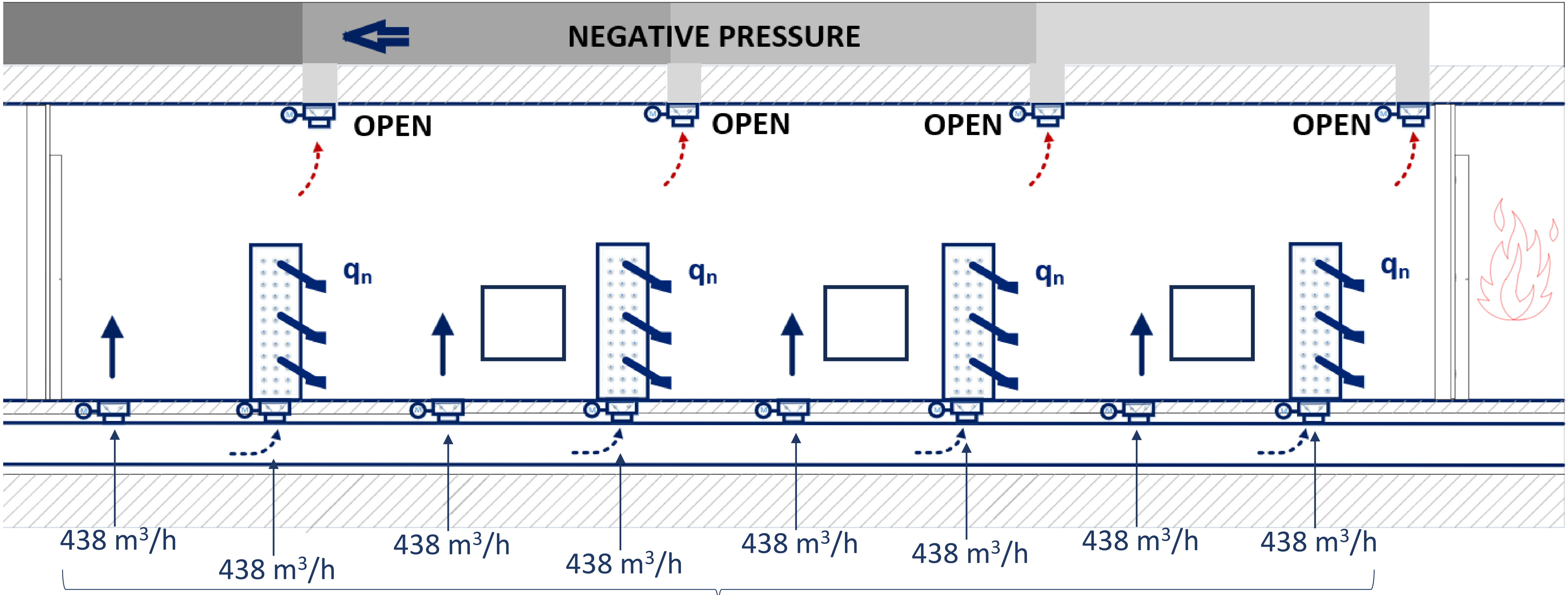
Affected compartment (max. 2)



Emergency Mode → Smoke & fire or helium leak scenario

2.6 Tunnel *Emergency Mode*

Adjacent compartment (max. 2)

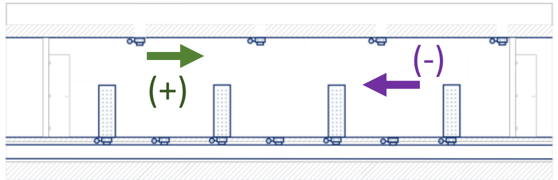


3500 m^3/h per compartment

Emergency Mode → Smoke & fire or helium leak scenario

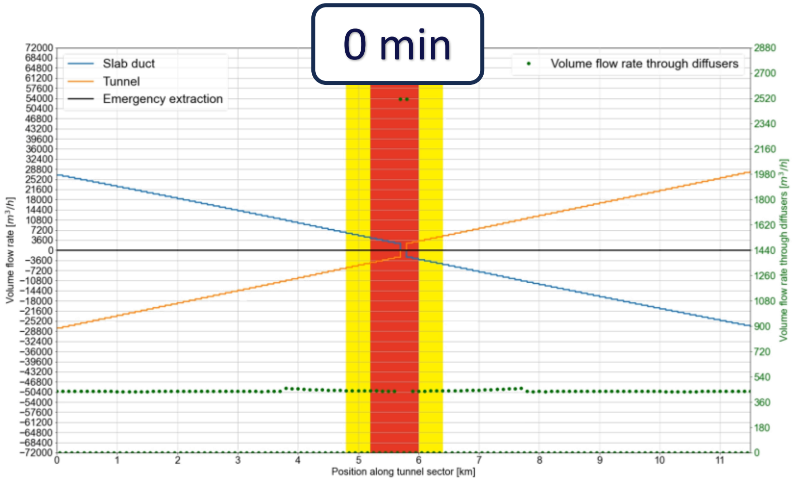
2.6 Tunnel

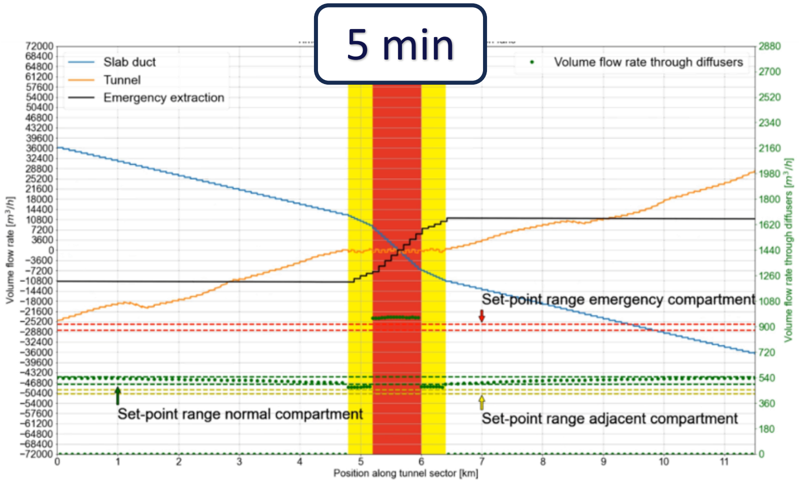
Emergency Mode
Transient, Run/Access → Emergency

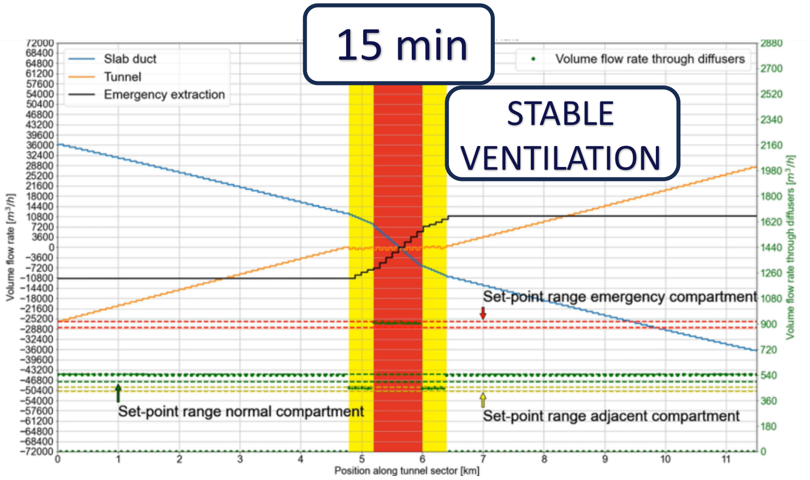


Signs criteria

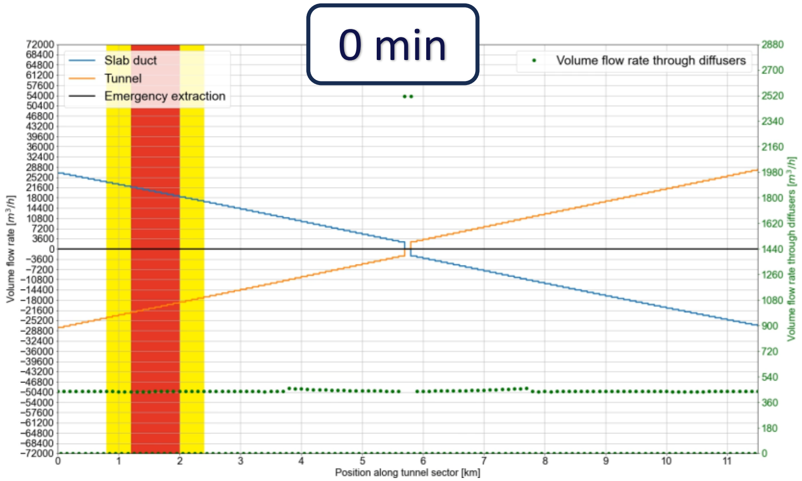
Emergency in center compartment

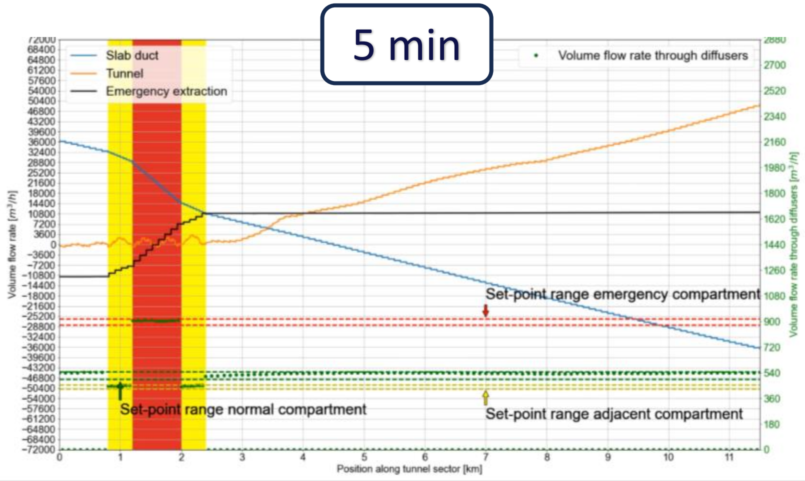


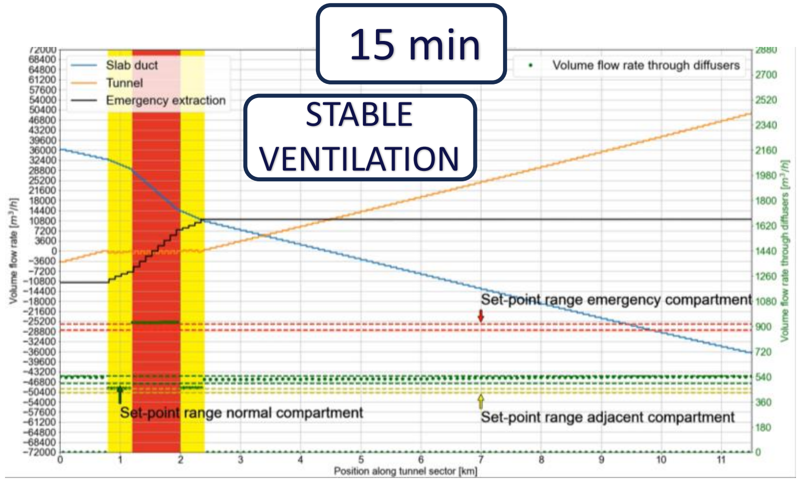




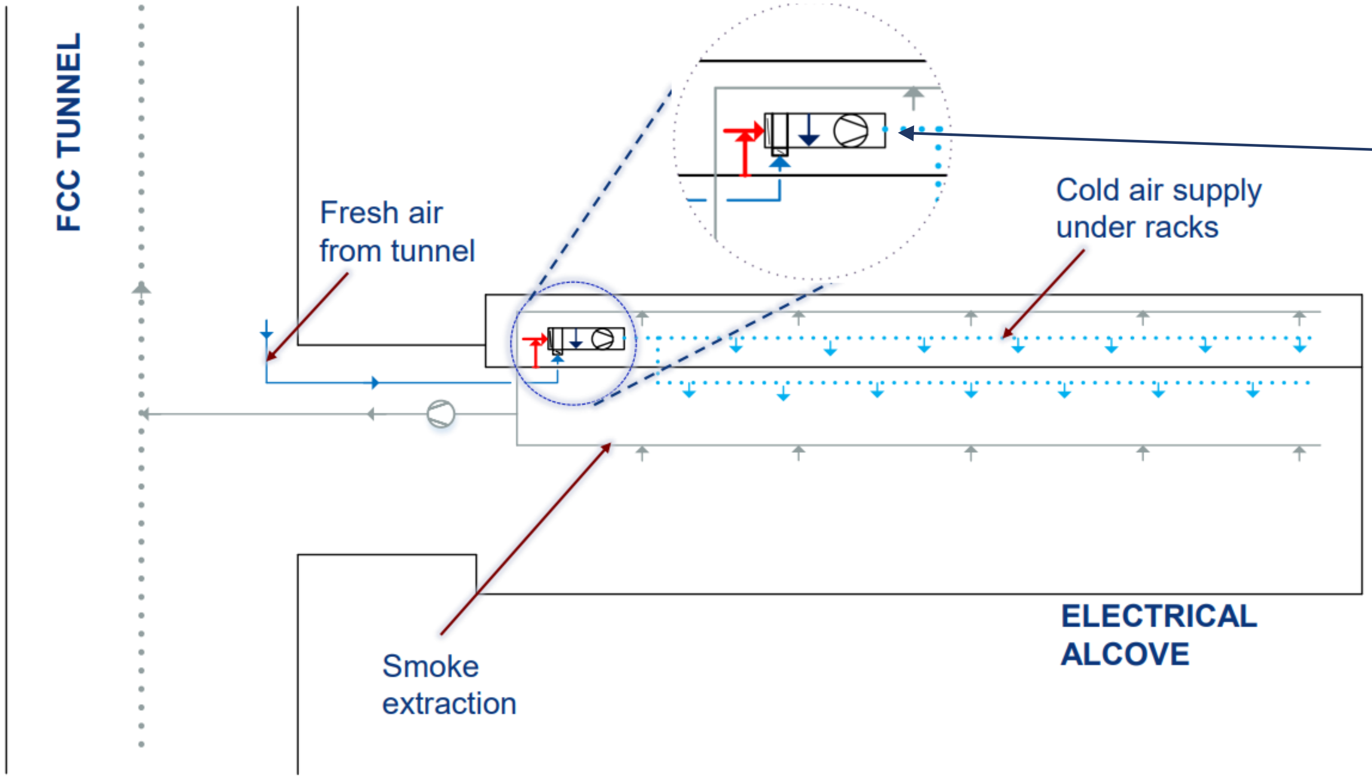
Emergency in lateral compartment

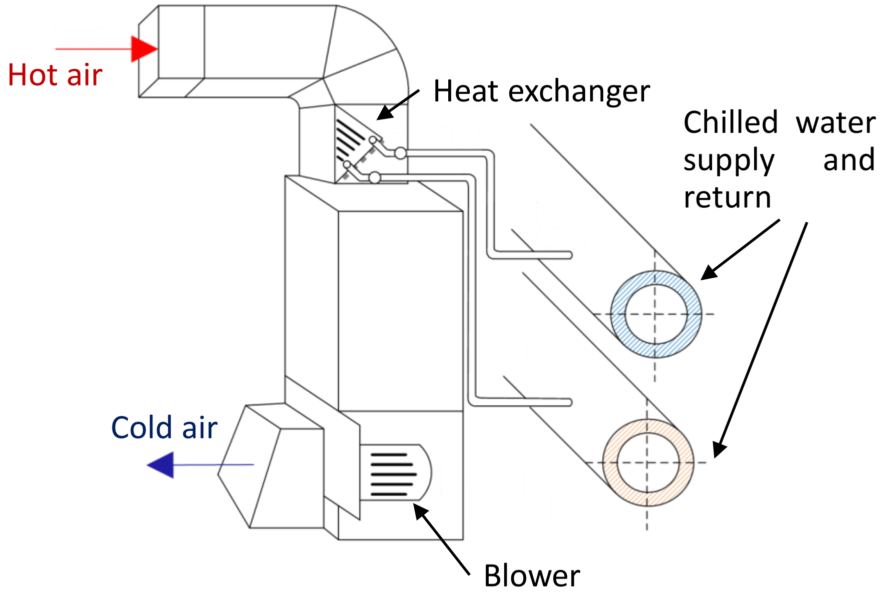


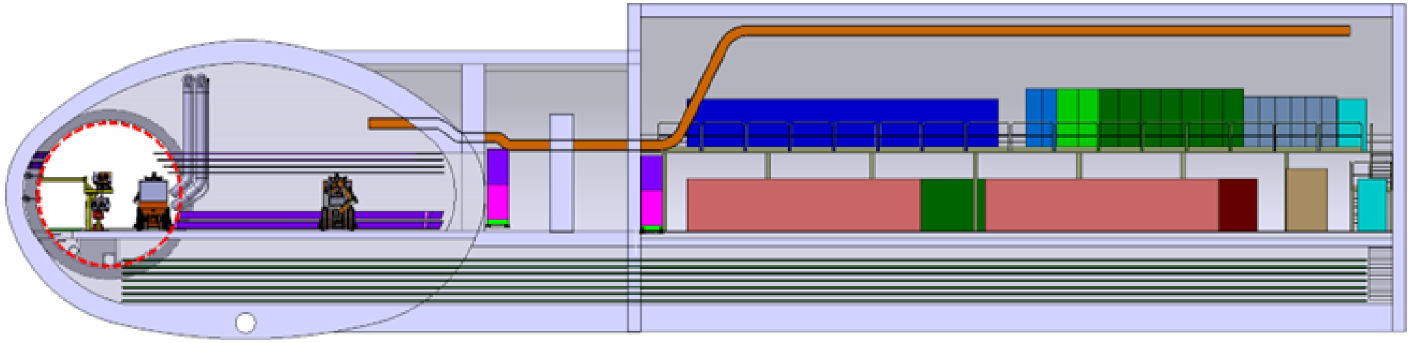




2.7 Alcoves *Ventilation*

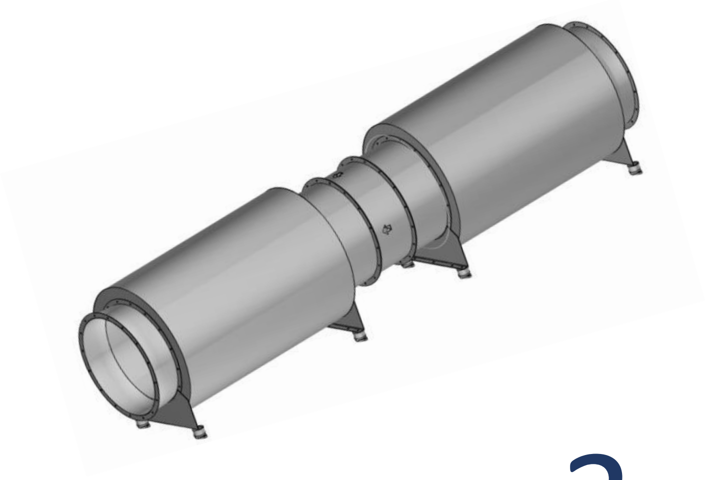


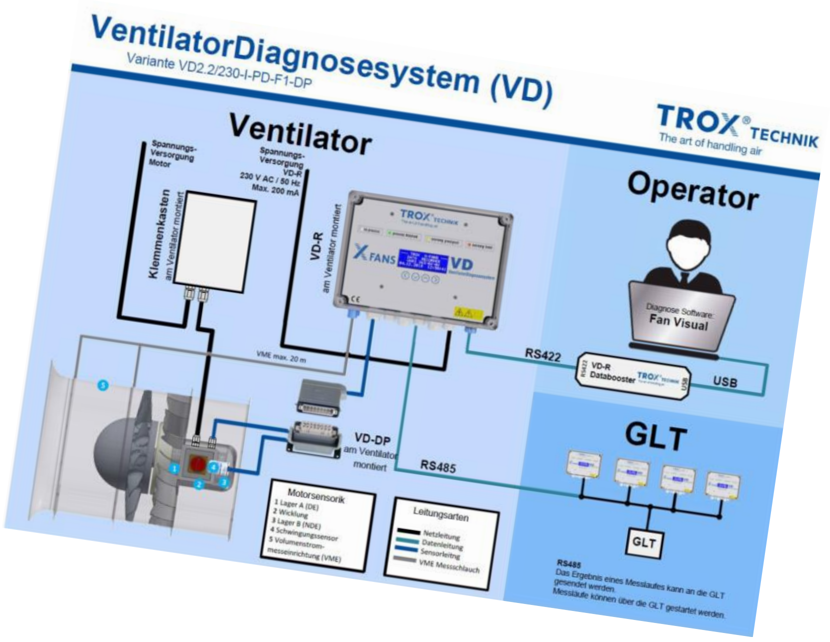


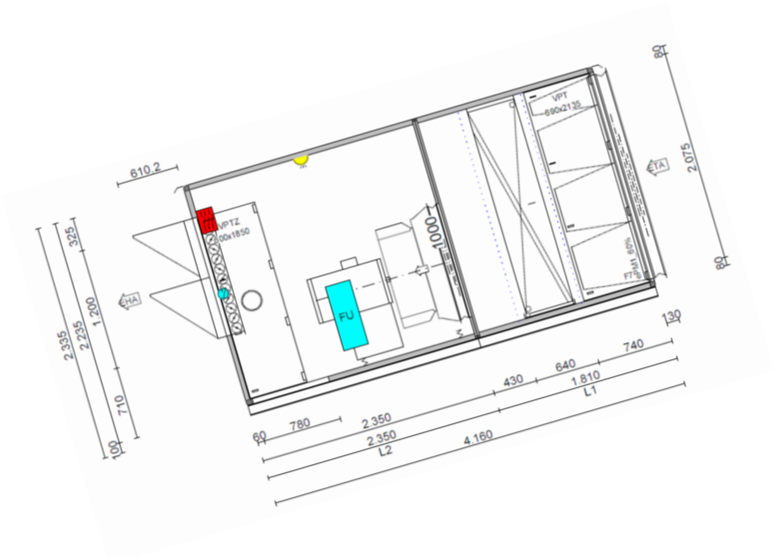


- Fresh air is supplied from the tunnel for the alcove ventilation. The exhaust air naturally flows towards the tunnel for extraction.
- Alcove ventilation load is transferred to chilled water.
- The smoke extraction is connected to the main smoke extraction duct of the tunnel.

More info:
F. Valchkova @ Session TIWG 3







3. Ongoing studies and topics

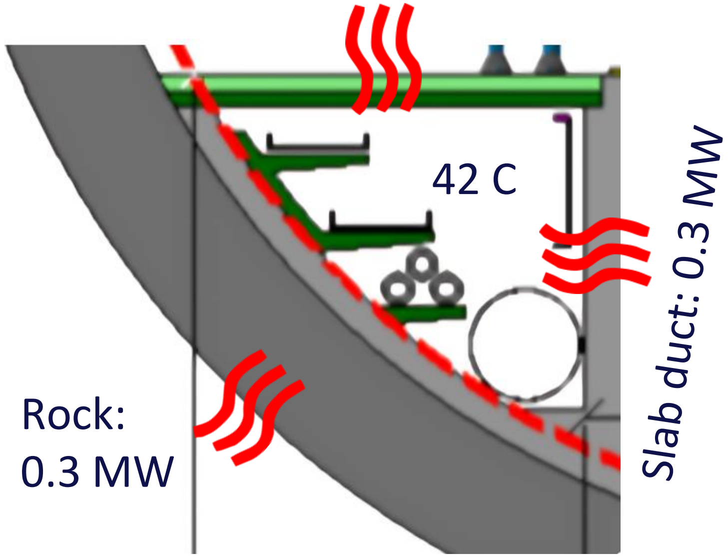
3.1 Cable heat load *To rock*

↑↑ Alcoves → ↓↓ Cable losses but… ↑↑ Civil Eng. cost

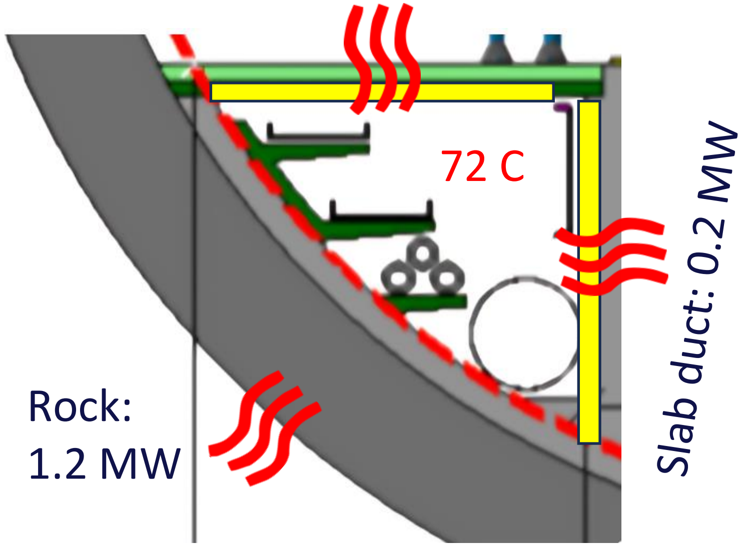
Cables losses → 1.8 MW per sector → 162 W/m

What if we could transfer some heat to the rock?

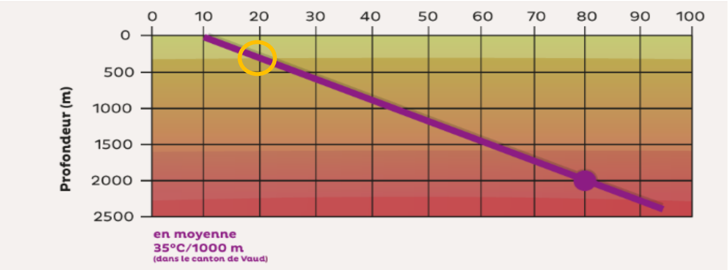
Without insulators



With insulators ~5 cm

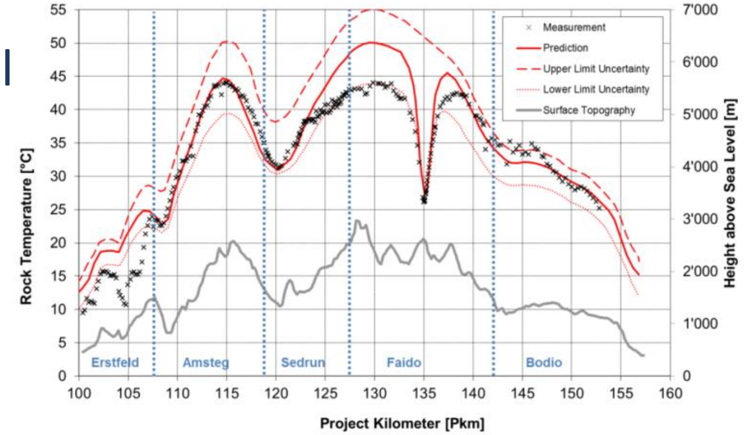


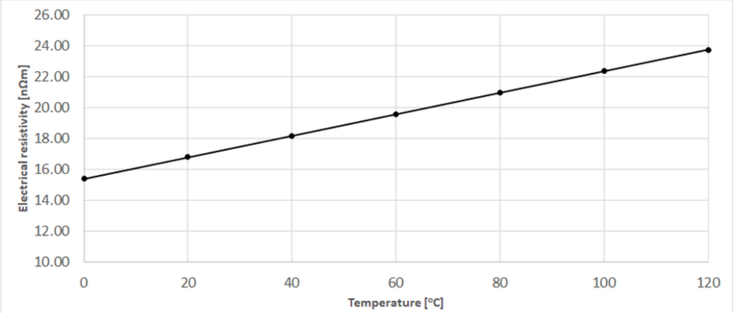
Cables would have to be bigger!



Evolution de la température dans le sous-sol dans les conditions du Plateau suisse. Source S. Catin CREGE

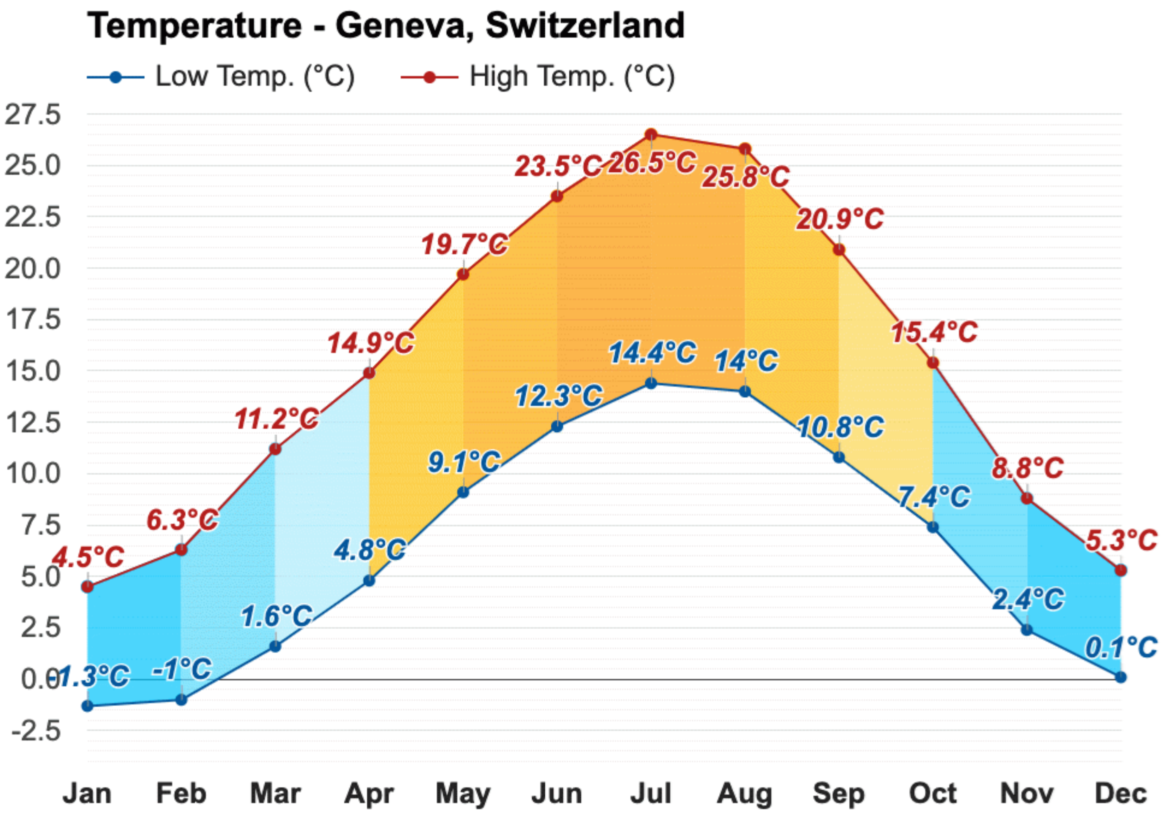
Gotthard Base Tunnel

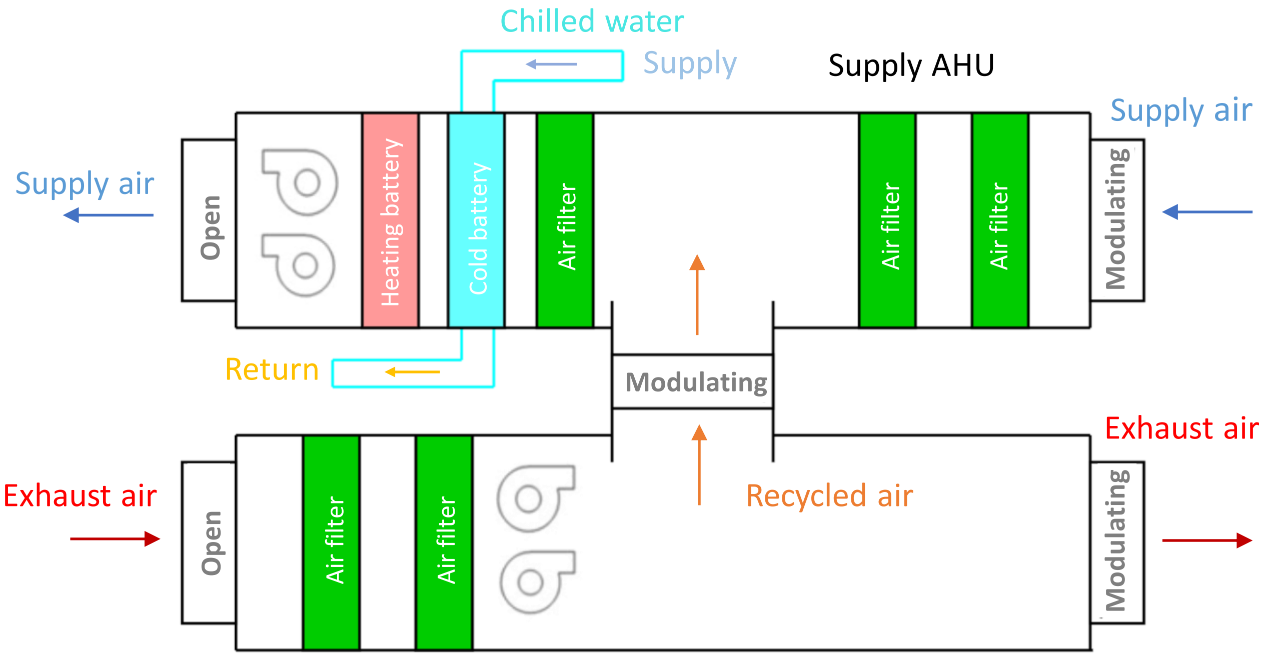




Temperature – resistivity copper

3.2 Air recycling *Run & Access Modes*





Run & Access Modes

Mode	Variable	T (°C)
Run	Max. Return T	32
	Min. Supply T	17
Access	Max. T Summer	26
	Min. T Winter	18

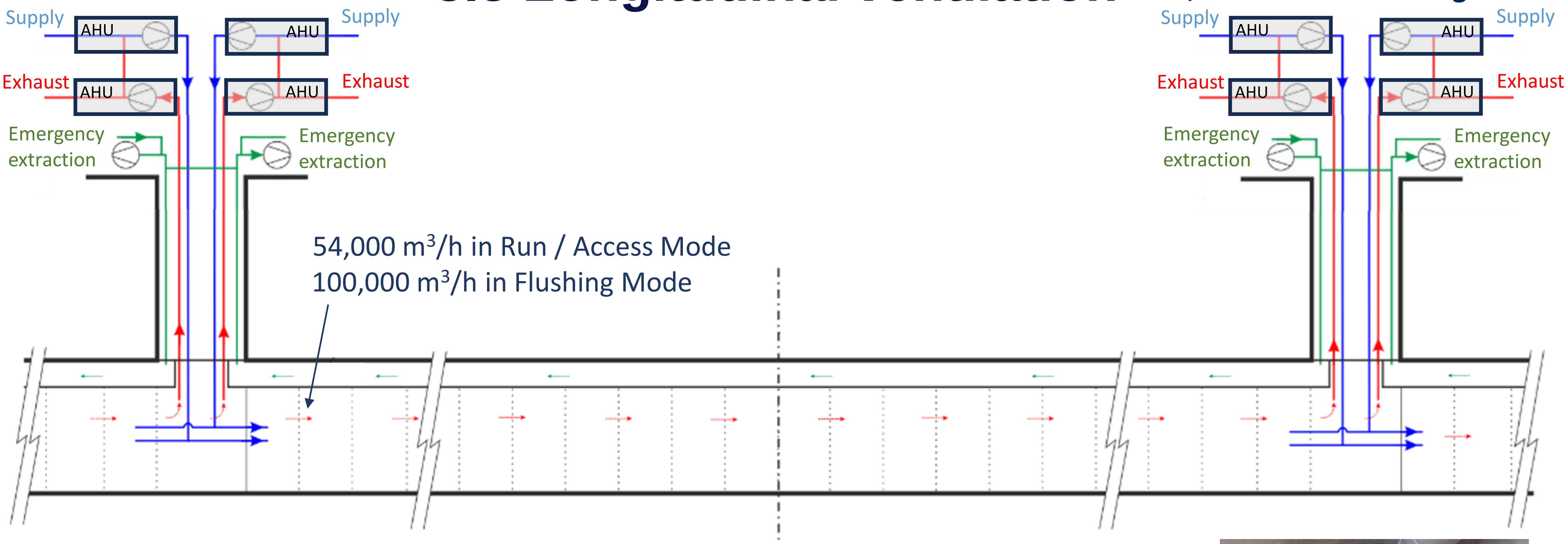
With very high or low temperatures (summer/winter), in principle, recycle as much as possible

In any case, always control according to external and internal temperature and humidity conditions.

Always considering the limits of RP, e.g. activated air

More info:
G. Lavezzari @ Session TIWG 1

3.3 Longitudinal ventilation *Run, Access & Flushing Mode*



Run Mode → Machine is in operation

Access Modes → Maintenance / works are done in the tunnel

Flushing Mode → Full air renewal between Access and Run Modes

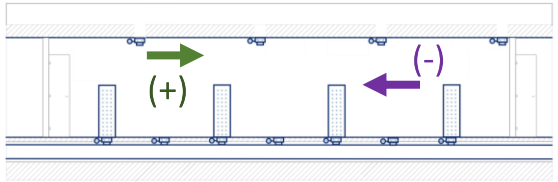
Advantages

- No slab duct needed
- Less and simpler controls (dampers,etc)
- More efficient overall, less pressure loss

Cross passage in the Gotthard Base Tunnel

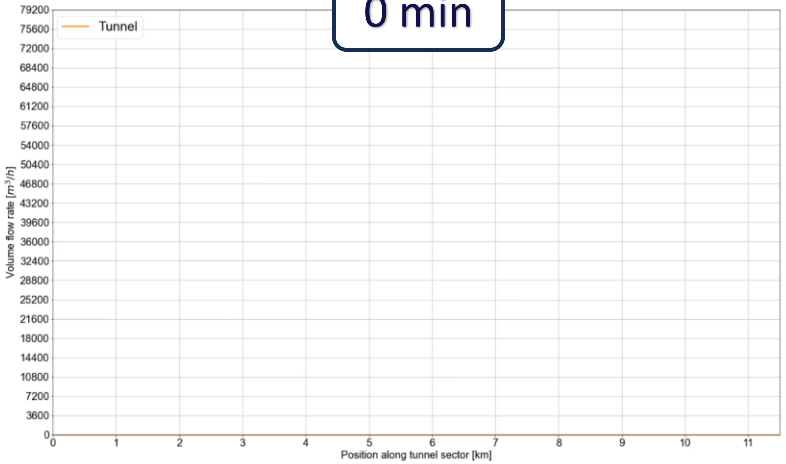
3.3 Longitudinal ventilation *Run, Access & Flushing Mode*

Transient, OFF → Run/Access

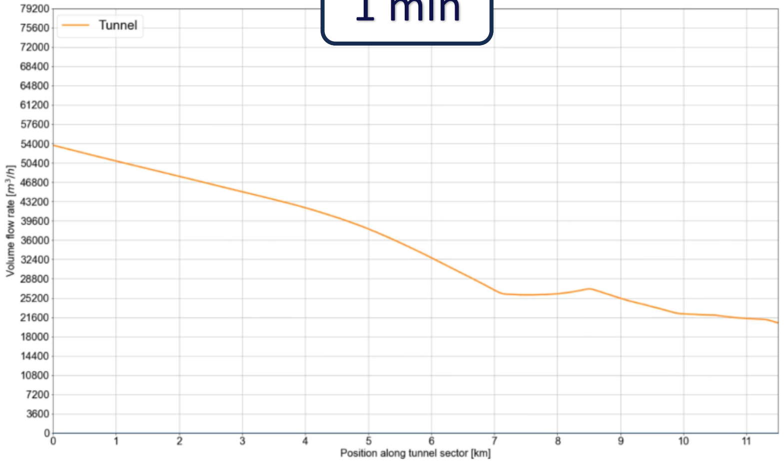


Signs criteria

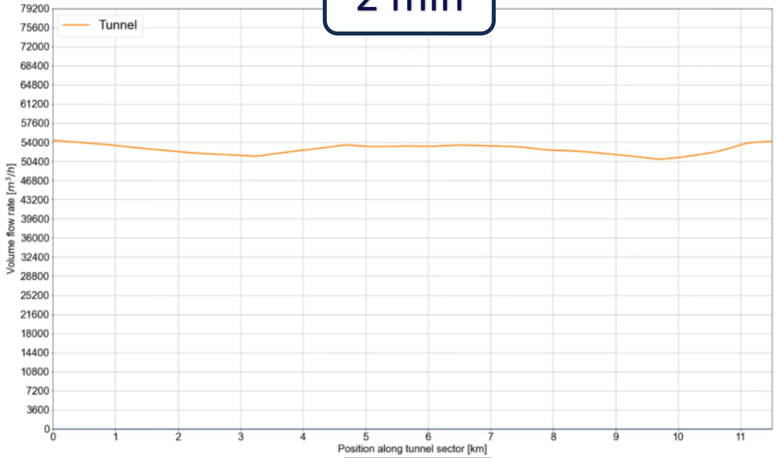
0 min



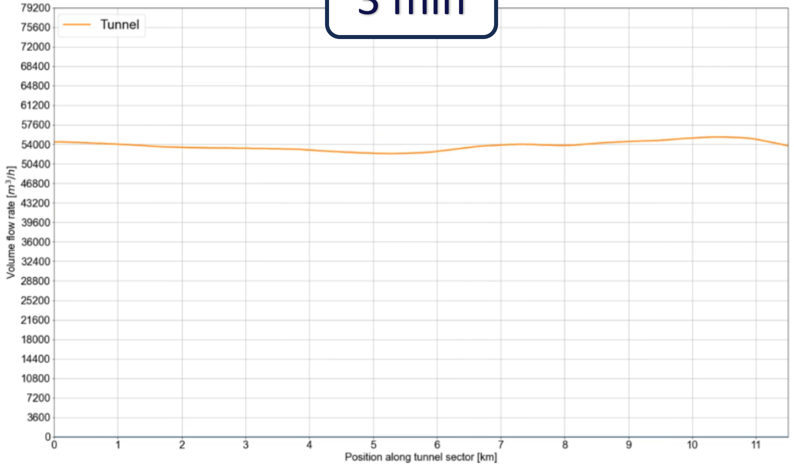
1 min



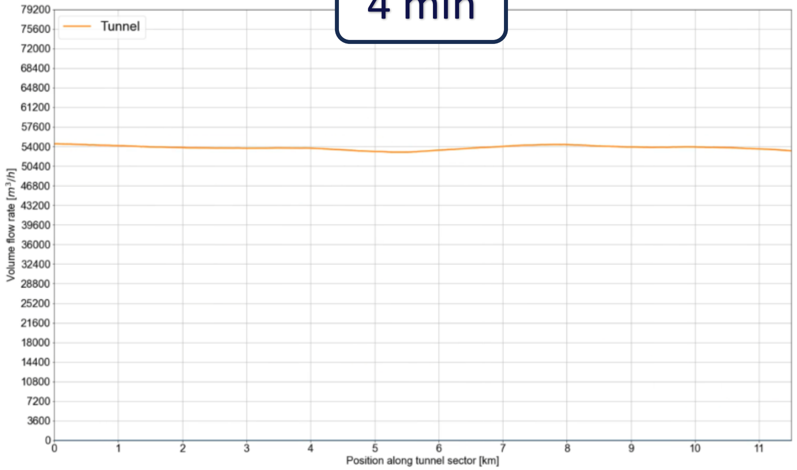
2 min



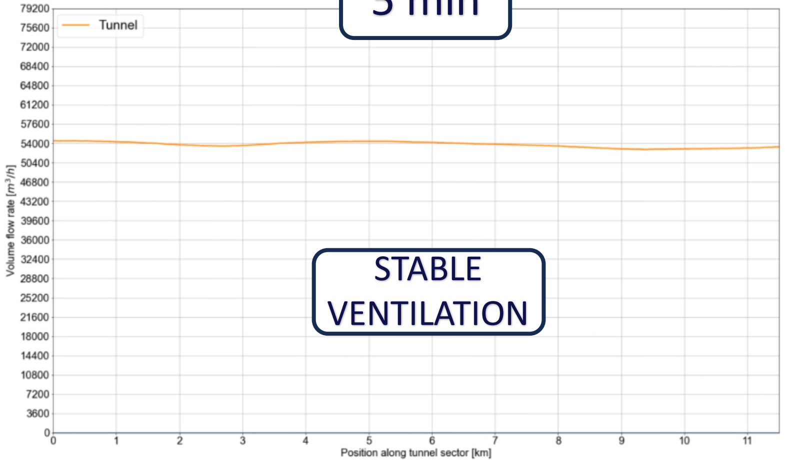
3 min



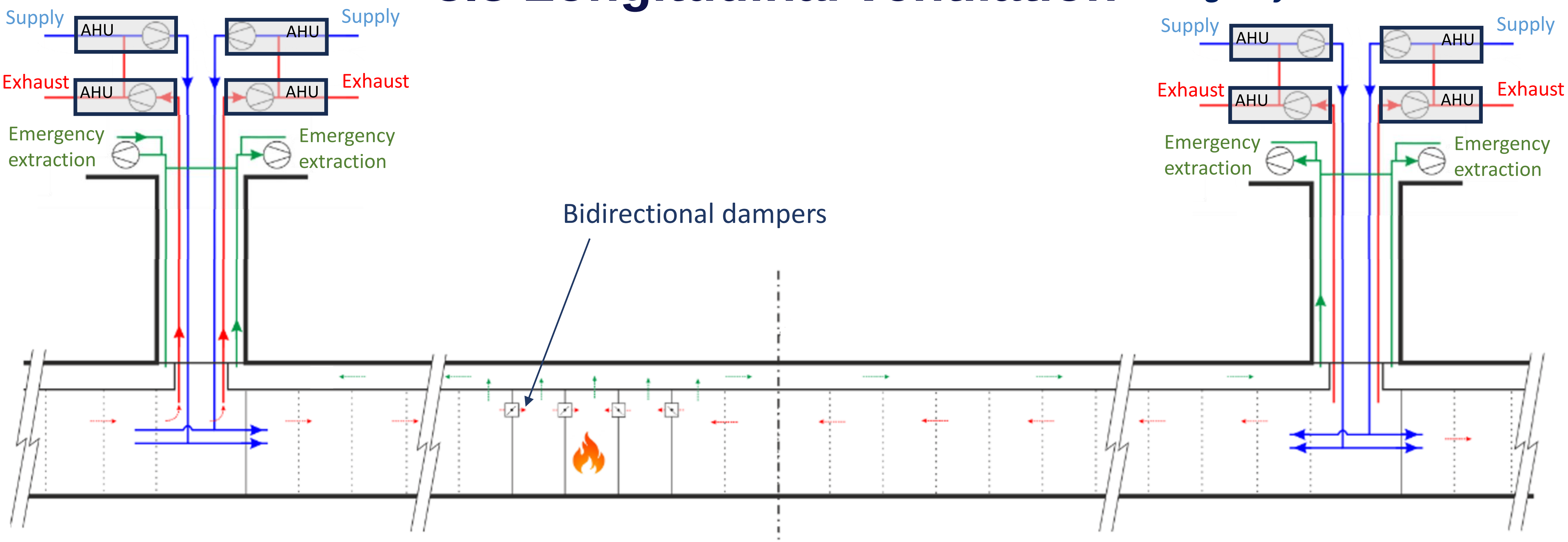
4 min



5 min



3.3 Longitudinal ventilation *Emergency Mode*



Emergency Mode → Smoke & fire or helium leak scenario

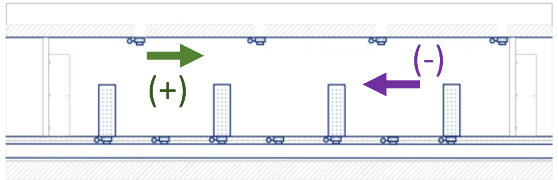
Disadvantages

- Degraded modes
- Force needed to open compartment doors
- Larger dampers at compartment walls

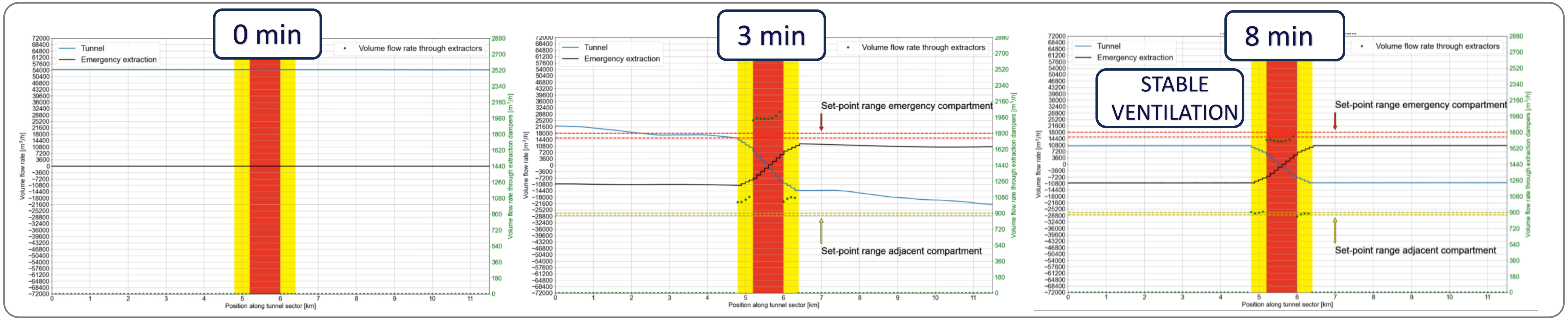
3.3 Longitudinal ventilation

Emergency Mode

Transient, Run/Access → Emergency

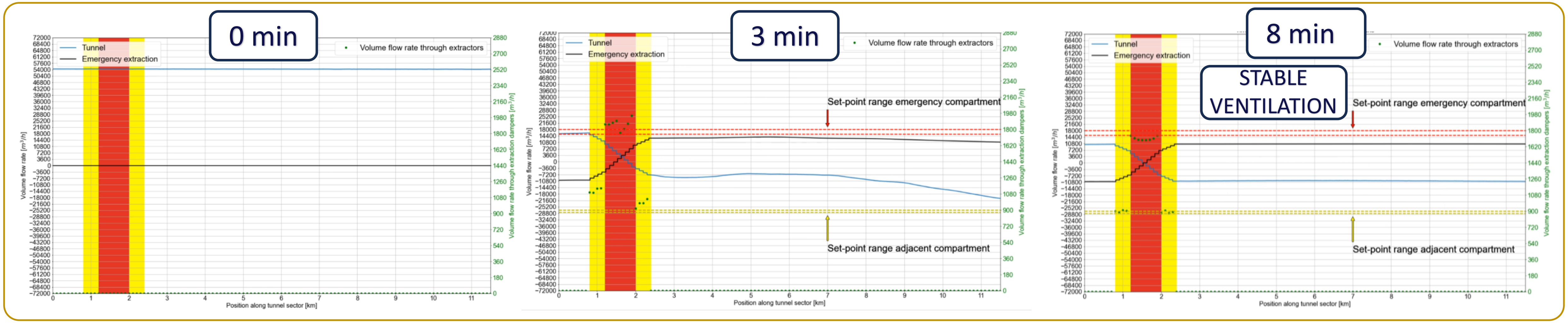


Signs criteria



Emergency in lateral compartment

Emergency in center compartment



3.4 Other zones

Ventilation requirements TBD

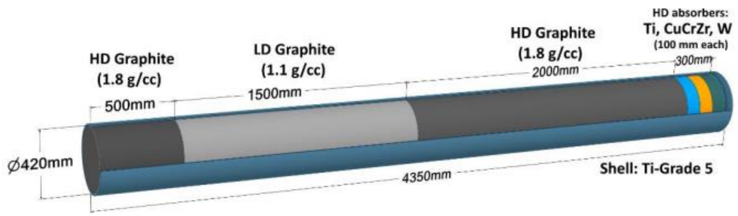
Other underground zones are not entirely defined yet

Information / boundary conditions collection of:

- Heat loads
- Temperature
- Air speed
- Humidity

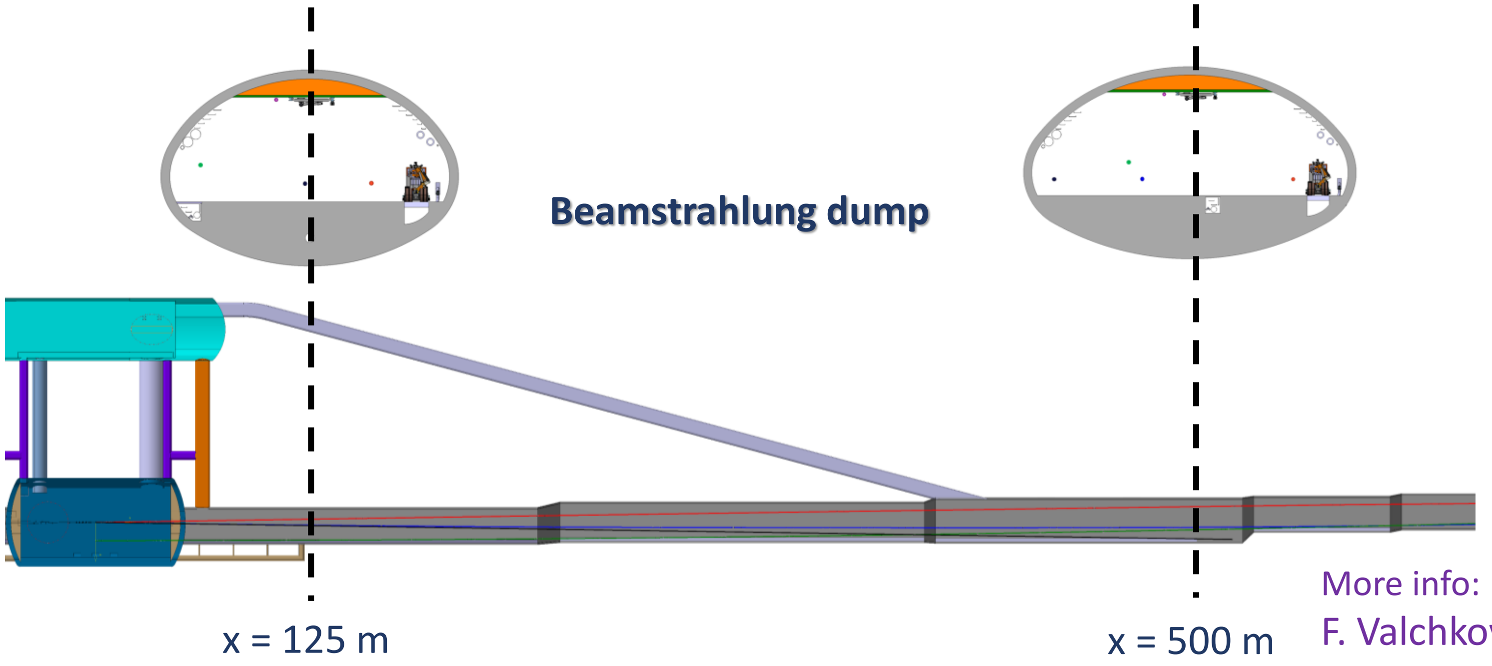
And other requirements (safety, radiation protection) from the users as more information is available.

Beam dump

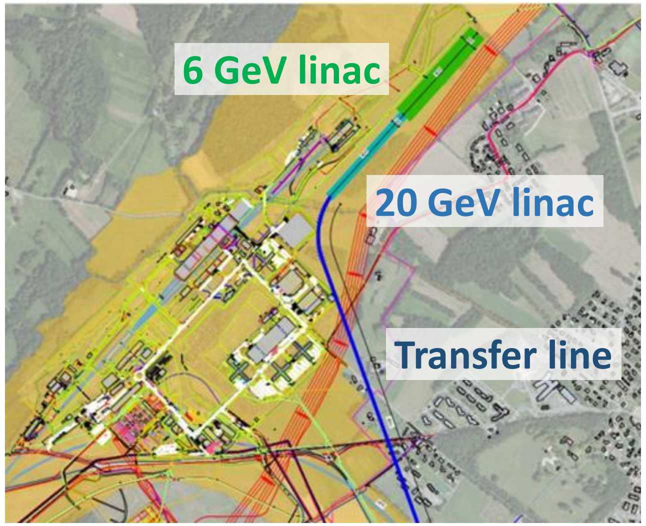


More info:
A. Krainer et al @ IPAC'22

Beamstrahlung dump

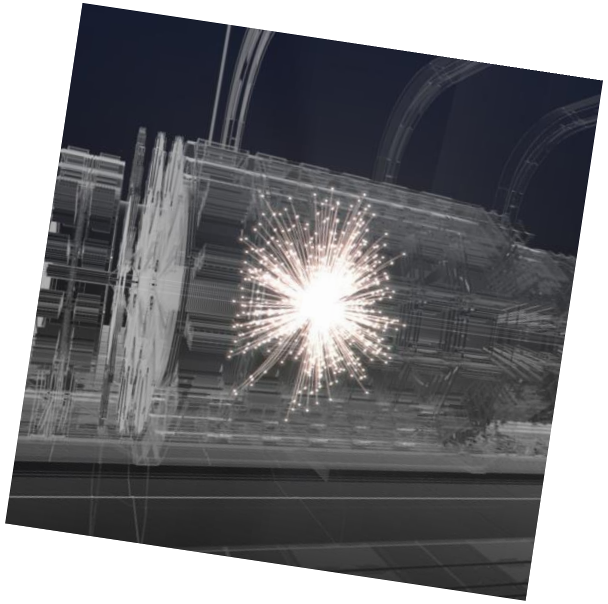


LINAC



More info:
F. Valchkova @ Session TIWG 3


SWITZERLAND
LHC
100 KM LONG
FRANCE
FCC
100 km Circumference



4. Next steps

4. Next steps

- Interact with the rest of departments and exchange information: heat loads, ducts integration, sustainability issues…
- Analyze and decide whether to continue with baseline ventilation or changing to the longitudinal concept
- Analyze and decide whether to implement other smaller proposals
- Write internally a final reference report on ventilation and develop the CV part to be included in the FCC Feasibility Study

Thank you
for your attention.

SPARES

EN-CV *Mandate & Structure*

Sectors, Departments and Units

CERN's structure

CERN's governance

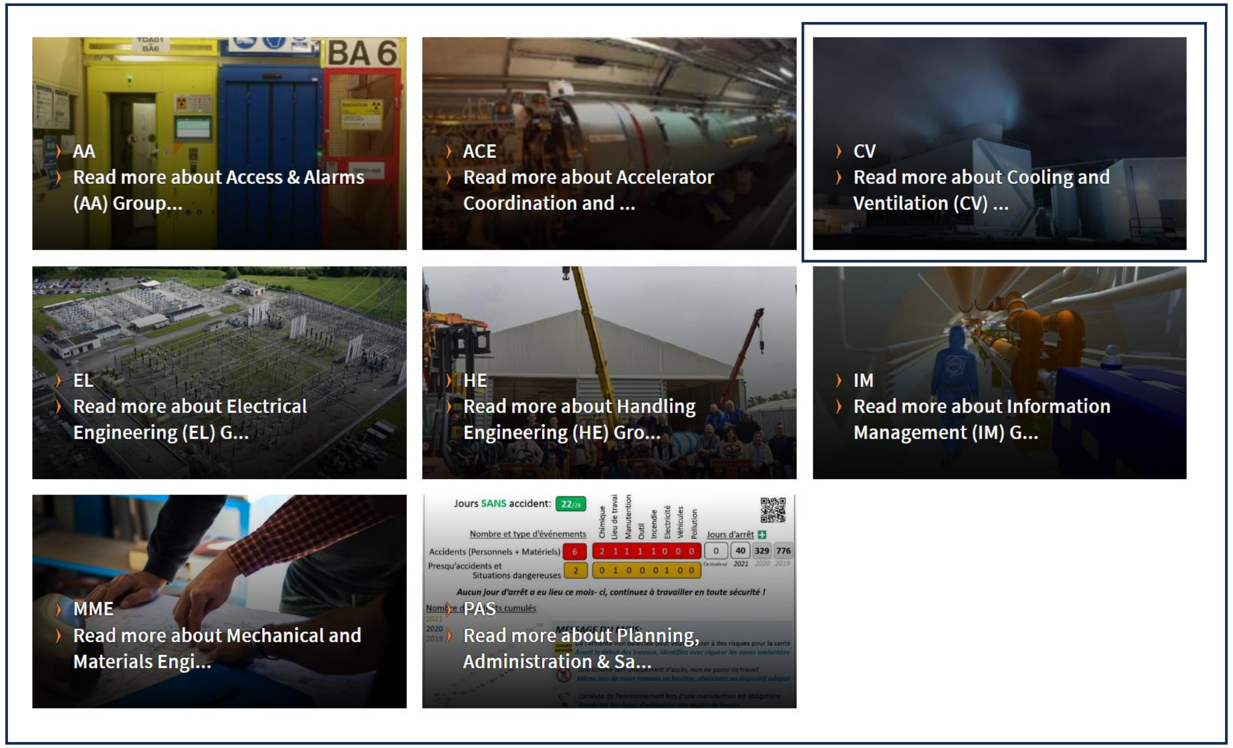
Director-General (DG)
- Health, Safety and Environment (HSE)
- Internal Audit (DG-IA)
- Legal Service (DG-LS)
- Translation, Minutes and Council Support (DG-TMC)

Accelerators and Technology (ATS)
- Beams (BE)
- Engineering (EN)
- Accelerator Systems (SY)
- Technology (TE)

Finance and Human Resources (FHR)
- Finance and Administrative Processes (FAP)
- Human Resources (HR)
- Industry, Procurement and Knowledge Transfer (IPT)
- Site and Civil Engineering (SCE)

International Relations (IR)
- Diplomatic and Stakeholder Relations (IR-DS)
- Education, Communications and Outreach (IR-ECO)

Research and Computing (RCS)
- Experimental Physics (EP)
- Information Technology (IT)
- Theoretical Physics (TH)
- Projects (RCS-PRJ)
- Scientific Information Service (RCS-SIS)



Engineering Department

Mandate:

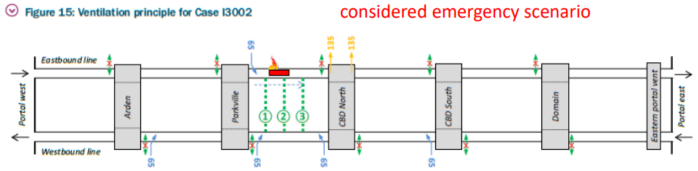
…design, installation, commissioning, operation and maintenance of the cooling systems, pumping stations, air conditioning plants and fluid distribution systems for the whole of CERN's accelerator complex…

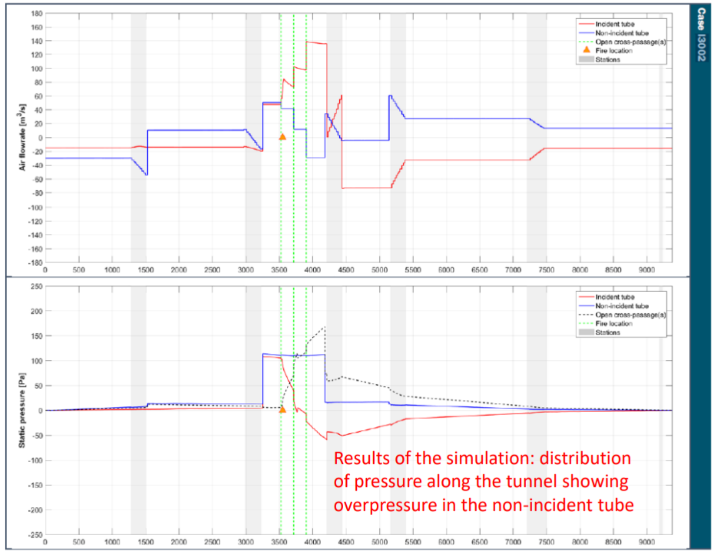
ThermoTun software *Transient simulations*

- 1D modelling software, developed by Dundee Tunnel Research and University of Dundee (Scotland).
- Transitory analysis of air pressures and velocities.

Metro Melbourne

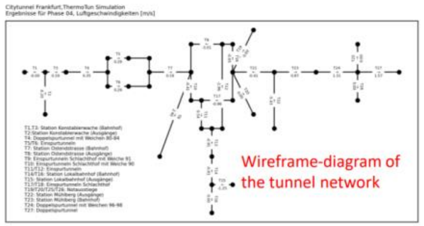
Schematics of the tunnel and the considered emergency scenario





Results of the simulation: distribution of pressure along the tunnel showing overpressure in the non-incident tube

Citytunnel Frankfurt



Wireframe-diagram of the tunnel network

Nachweis für Phase 4:

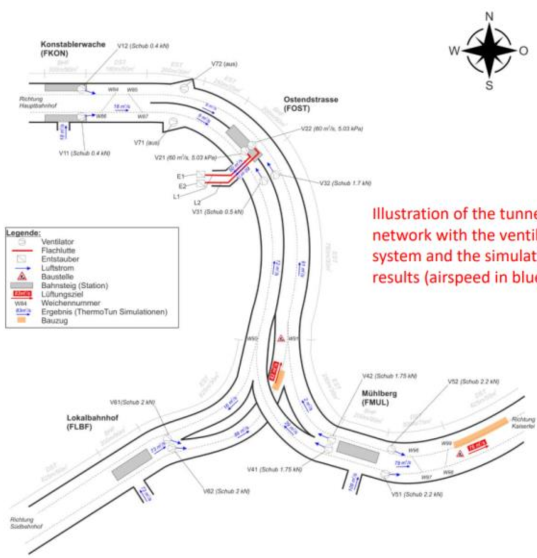
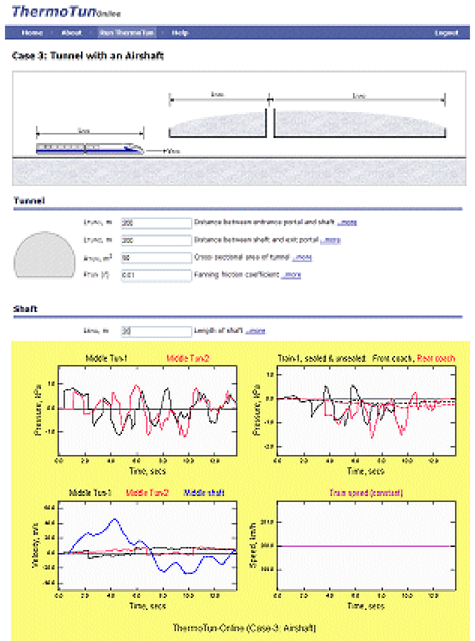
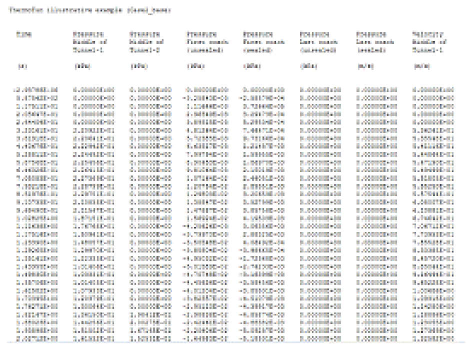


Illustration of the tunnel network with the ventilation system and the simulation results (airspeed in blue)





Simulations *Configuration*

Both the baseline, semi-transverse concept and the alternative, longitudinal concept are included in the simulations.

Simulation of the Run Modes.

- Supply fans ramp up time: 60 s
- Setpoint in damper of baseline concept ramp up time: 100 s

Easy controller 227V-024T-05-013	
Supply voltage ~	24 V AC ± 20%, 50/60 Hz
Supply voltage ⎓	24 V DC ± 20 %
Power rating ~	5 VA max.
Power rating ⎓	Max. 3 W
Run time for 90°	100 s
Setpoint value signal input	0 – 10 V DC, Ra > 100 kΩ
Actual value signal output	0 – 10 V DC, max. 0.5 mA
IEC protection class	III (protective extra-low voltage)
Protection level	IP 20
EC conformity	EMC to 2014/30/EU

Simulation of Emergency Modes.

- Timeline of events for transition from Run to Emergency Modes

Time [s]	Event	Comment
<0	Normal operation mode	
0	Fire detection, alarm given	A reaction time/delay of 60s until confirmation of the fire alarm by the operator and/or activation of corresponding scenario is assumed
60	Stop normal ventilation (supply and normal extraction)	Avoid spread of smoke along the tunnel
60	Close doors of fire affected and adjacent compartments	Time to close: 30 s
60	Open emergency extraction dampers in ceiling duct of the fire affected and adjacent compartments	Time ot fully open the dampers: 30s
90	Start emergency extraction fans	Ramp up time for emergency extraction fans: 30s
90	Restart supply flow with distribution according to position of fire	Time to achieve target supply distribution: as per system reaction time accounting for VAV dampers opening/closing speed (100s from fully open to fully closed)

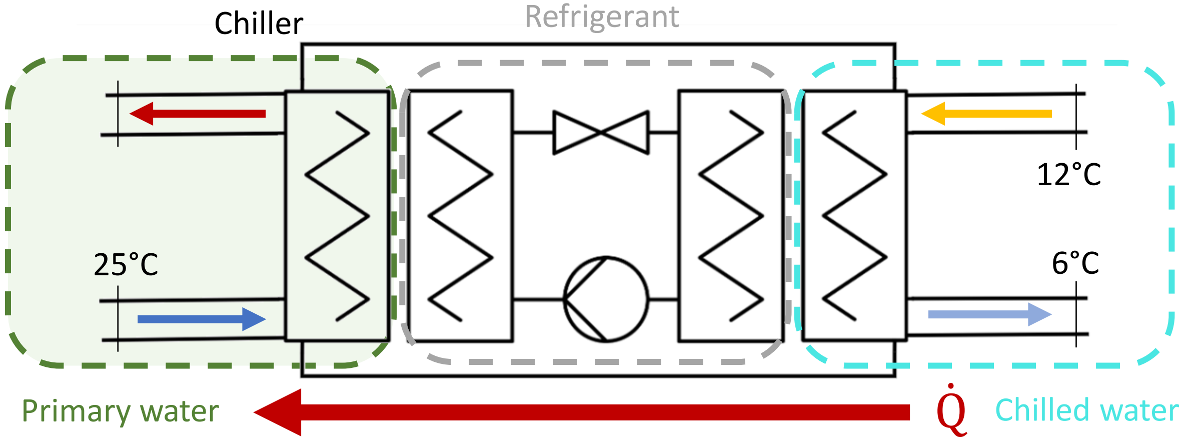
If cables = 3,500 kW

2.1 Generalities

Primary circuit heat loads

FCC-ee COOLING POWER NEEDS FOR PRIMARY CIRCUITS (MW)

Point	Cryogenics	Experiment	General Services	Power Converters (RF)	Chilled water	Underground	TOTAL
A	0.3	0.5	2		~~4.6~~ *6.8*	42.6	~~50~~ *52*
B			2		~~3.9~~ *6.2*	1.0	~~7~~ *9*
D	0.3	0.5	2		~~4.6~~ *6.8*	42.6	~~50~~ *52*
F			2		~~3.9~~ *6.2*	1.0	~~7~~ *9*
G	0.3	0.5	2		~~4.6~~ *6.8*	42.6	~~50~~ *52*
H	34		2	4.5	~~10.1~~ *12.3*	51.0	~~102~~ *104*
J	0.3	0.5	2		~~4.6~~ *6.8*	42.6	~~50~~ *52*
L	10		2	0.1	~~4.5~~ *6.8*	2.7	~~19~~ *22*



Ventilation cooling requirements
in Primary Water Circuit

More info:
G. Peon @ Session TIWG 5

If cables = 3,500 kW

2.1 Generalities

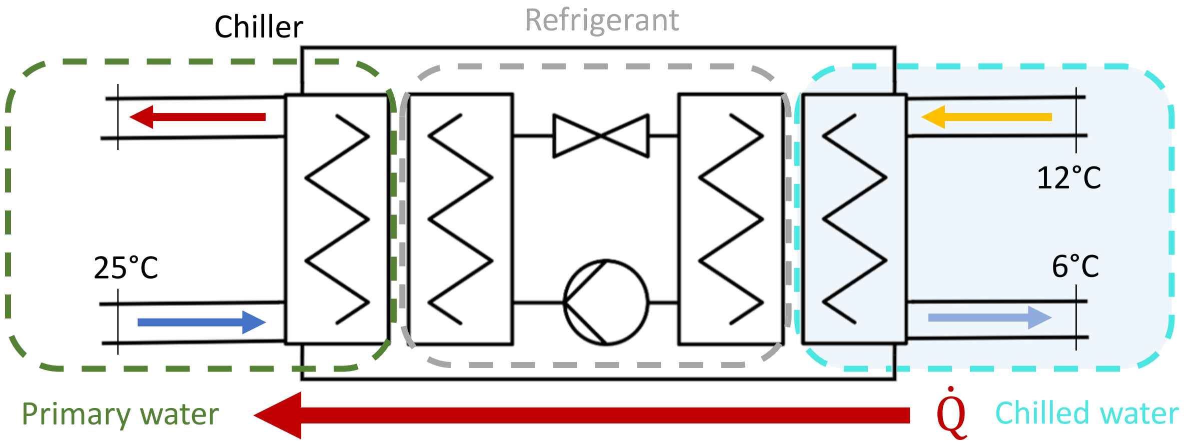
Chillers needed

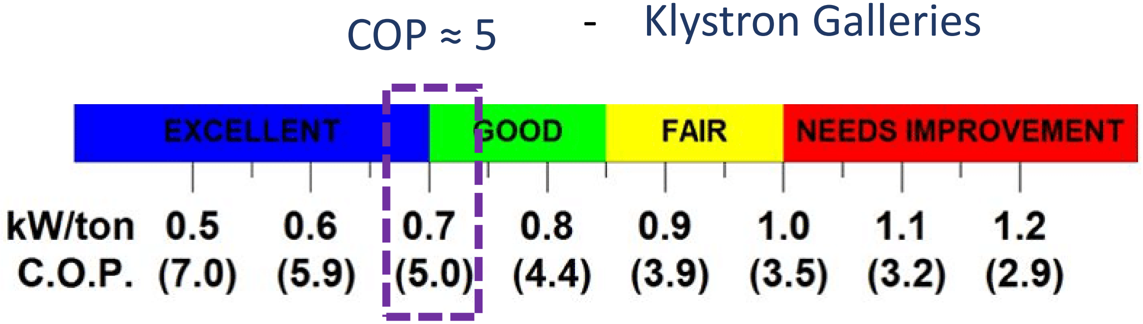
POINT	COOLING POWER (kW)	FLOW RATE (m^3/h)	NUMBER OF CHILLERS	COOLING POWER/ CHILLER (kW)
A	~~3,848~~ *5706*	~~553~~ *820*	~~5~~ *7*	1,000
B	~~3,284~~ *5142*	~~472~~ *739*	~~5~~ *7*	900
D	~~3,828~~ *5686*	~~550~~ *817*	~~5~~ *7*	1,000
F	~~3,284~~ *5142*	~~472~~ *739*	~~5~~ *7*	900
G	~~3,848~~ *5706*	~~553~~ *820*	~~5~~ *7*	1,000
H	~~8,345~~ *10203*	~~1,200~~ *1,467*	~~6~~ *7*	1,800
J	~~3,828~~ *5686*	~~550~~ *817*	~~5~~ *7*	1,000
L	~~3,739~~ *5597*	~~537~~ *805*	~~5~~ *7*	1,000

Ventilation cooling requirements in Chilled Water Circuit.

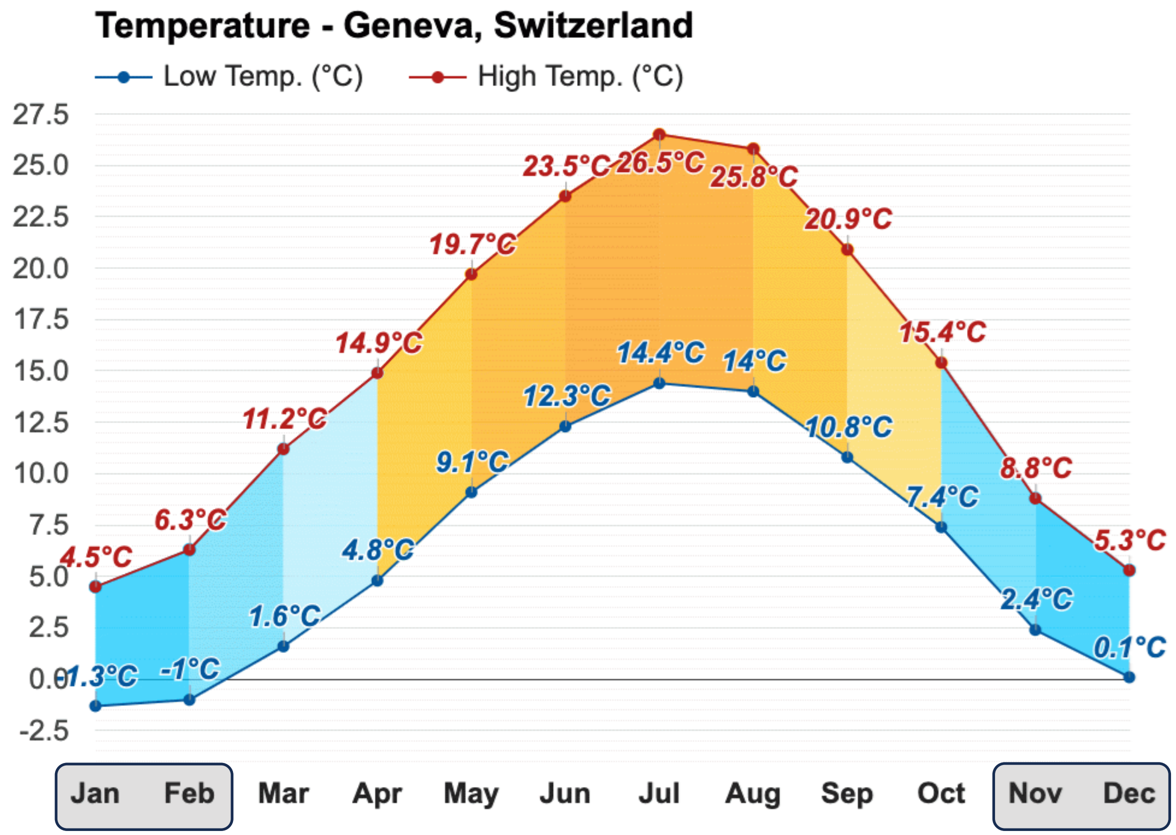
Cold batteries in AHUs / Fancoils in:

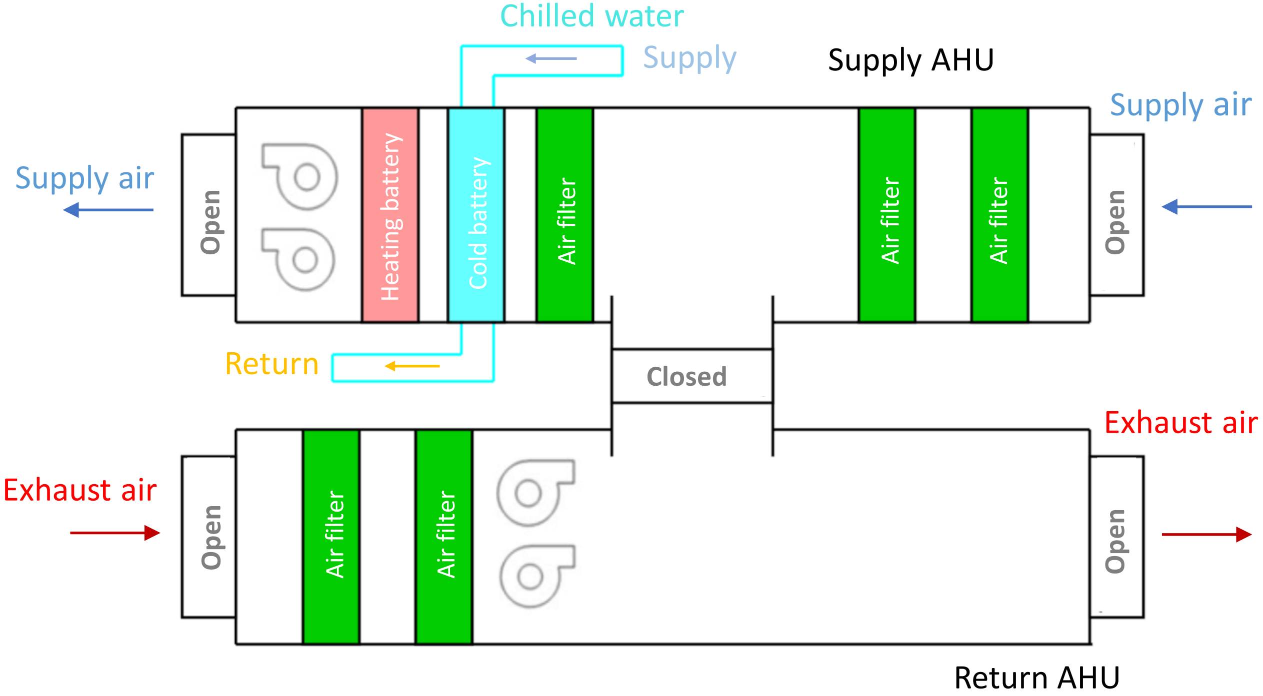
- Surface Buildings
- Shaft pressurization
- Service Cavern & UAs
- Experimental Cavern
- Half Tunnel Sector 1
- Half Tunnel Sector 2
- Klystron Galleries





3.2 Air recycling *Flushing Mode*





Flushing Mode

Mode	Variable	T (°C)
Flushing	Max. Supply T Summer	26
	Min. Supply T Winter	15

In case of extremely low temperatures during Flushing, when the Heating battery cannot achieve the 15 °C:

↓↓ Air flow until T_{supply} = 15 °C but… ↑↑ Flushing time